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Army Overseas Water Sustainability Study

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Abstract

A key concern for the US Army is the vulnerability of military installations to critical resource issues. Water issues of concern (adequate supply, cost of production, quality, habitat degradation, and salinity) already impact military installations and military operations around the globe. There is a need to assess vulnerability of regions and installations to water supply and to develop strategies to ameliorate any adverse effects on military sustainment. This work assessed regional water scarcity as it affects Army installations in three overseas locations (US Army Garrison Grafenwöhr, Germany; US Army Garrison Vicenza, Italy; and US Army Garrison Humphreys, Korea) to ensure continued viability and sustainability of Army operations.

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Preface

This study was conducted for the Army Environmental Policy Institute under Project, “Army Overseas Water Sustainability Assessment,” Work Unit 4H9044. The technical monitor was Marc Kodack, Senior Fellow, Army Environmental Policy Institute (AEPI).

The work was managed and executed by the Energy Branch (CF-E) of the Facilities Division (CF), and the Ecological Processes Branch (CN-N) of the Installations Division (CN), US Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL). The CERL principal investigator was Elisabeth M. Jenicek (CF-E). Part of this work was completed by Laura Curvey of the University of Illinois at Urbana-Champaign (UIUC) under Contract W9132T-10-C-0010. Special appreciation is owed to the following installation points of contact for providing information that was invaluable to this study and for reviewing this report: Stefan Kunz, US Army Garrison Grafenwohr; Michael Sartori, US Army Garrison Vicenza; and Michael Barenburg, US Army Garrison Humphreys. Franklin H. Holcomb is Chief, CEERD-CF-E, and L. Michael Golish is Chief, CEERD-CF. The associated Technical Director was Martin J. Savoie, CEERD-CV-T. William D. Goran is the director of the Center for Advancement of Sustainability Innovations (CASI). The Deputy Director of ERDC-CERL is Dr. Kirankumar Topudurti and the Director is Dr. Ilker Adiguzel.

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1 Introduction

Background

A key concern for the US Army is the vulnerability of military installations to critical resource issues. Water issues of concern—including adequate supply, increased cost of production per unit volume, quality, habitat degradation, and salinity—already impact military installations and military operations in many locations within the nation and around the globe. There is a need to assess vulnerability of regions and installations to water supply and to develop strategies to ameliorate any adverse effects on military sustainment. This report is an initial screening of water conditions in regions hosting US Army installations specific to Germany, Italy, and Korea. It is the first key step in the process that may identify additional recommended studies, planning, and actions.

The US Army has long recognized the emergence of water scarcity as an issue of concern, and includes water efficiency statements and goals in Army sustainability directives. In the utilities arena, water policy is closely associated with energy issues and policy. National policy, such as US Energy Independence and Security Act of 2007 (EISA 2007) and Executive Order (EO) 13423, are captured in documents such as the Installation Management Campaign Plan.

The study documented in this report is one in a series supported by the Army Environmental Policy Institute (AEPI). Previous reports developed methodologies for conducting national watershed screenings, creating regional water budgets, and projecting installation water demand based on alternate future scenarios. The purpose of these studies is to inform Army leadership about issues affecting installation water sustainability to affect changes in Army policy.

Army installations are widespread, located in a wide range of geographies and climate regimes. Globally, enduring installations are located in the United States, Germany, Italy, Korea, and Japan. Additionally, Forward Operating Bases (FOBs) and sites can be found in Romania, Bulgaria, Iraq, Afghanistan, and the African continent.

This study examines water sustainability at three enduring Army installations overseas. all three of which have experienced or are experiencing the

challenges that accompany transformation initiatives. In addition, each is subject to a unique set of regional stressors that affect water sustainability.

US Army Garrison Grafenwöhr, Germany transformed from a population of 9963 (2006) to 15,930 (2008) as the result of Efficient Basing Grafenwöhr. Issues of general concern in Germany include uneven distribution of precipitation, conflicts over the use of water bodies, regional shortfalls of drinking water, and non-point source pollution. Expected impacts of climate change in Germany include changes in precipitation (more in winter, less in summer) and warmer overall temperatures. Located in northern Bavaria, Grafenwöhr is fortunate to reside in a region of abundant water resources with little competition for their use. Water quality issues that exist elsewhere in Germany are not a problem here.

US Army Garrison Vicenza, Italy is located in the Veneto region of the upper northeast of Italy. Vicenza currently has a population of 12,814 (2009), and will ultimately house 17,578 military, civilians, and family members as the 173rd Airborne Brigade is consolidated with the Dal Molin facility. Issues of general concern in Italy include local conflicts over water, lack of access to relatively abundant water resources, non-authorized withdrawal of groundwater, unaccounted for water, overexploitation of aquifers in coastal zones, and point source and diffuse pollution. Expected impacts of climate change in Italy include temperature rise, receding Alpine glaciers, and changes in precipitation (less in the South, more in the North), more extreme climate events, and eventual reduction in overall precipitation. Although Italy is challenged by a number of water issues, Veneto (with its artesian springs) is relatively water rich.

US Army Garrison Humphreys, Korea (USAG-H) is currently engaged in a series of transformation initiatives that will triple the installation's population for an end state of 53,943 (fiscal year [FY] 2020). This projected total does not include any potential increase should the Tour Norm initiative be enacted. Water issues of general concern in Korea include increasing demand, fluctuating supply, limited access to relatively abundant water resources, water quality, and water storage planning. While relatively rich in precipitation, Korea suffers from seasonal extremes and lack of adequate containment to sustain the nation through increasingly frequent drought seasons. Expected impacts of climate change in Korea include temperature increase, increases in precipitation, greater seasonal swings causing both drought and flooding, and more extreme weather events.

Objectives

The objective of this study is to provide an assessment of regional water scarcity as it affects Army installations in these overseas locations to ensure continued viability and sustainability of Army operations.

Approach

Installation water scarcity was assessed by applying methods for conducting a regional water balance (or budget) at three installations. Regional water budgets identify sources of water supply and demand for the water resources used by Army installations. The product is an input-output model of regional water supply and demand. Model variables were altered to produce alternate future scenarios and evaluate the potential impact on availability of water for Army installations.

The Installation Water Demand Model* was used to develop water use estimates projecting 30 years into the future. The model uses installation-specific data about historic water use and existing and planned building stock to project future demand. Regional water demand is calculated using historic regional water data, existing and planned water conservation measures, and projected population changes.

Mode of technology transfer

It is anticipated that the results of this assessment will be used to formulate strategies for achieving water efficiency goals and to present recommendations for changes to Army policy to plan for a secure water future. This research will be presented at workshops and symposia, and this report will be made available through the World Wide Web (WWW) at the following public URL: <http://www.cecer.Army.mil>

* Both the regional water balance method and the Installation Water Demand Model are documented in Jenicek et al. (2009).

2 Water Vulnerability Issues for Overseas Installations

Fresh water is a fundamental requirement of life on earth. Though 70 percent of the planet's surface is covered in water, less than 3 percent is fresh; the rest is undrinkable seawater. Most of the fresh water is contained in glaciers and ice caps. The uneven global distribution of fresh water leaves one in six (1.1 billion) people without access to this necessity (WHO/UNICEF 2005). Water is such a critical resource that it was included in Millenium Development Goal 7,* which is to "halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation." As world population grows—estimated to reach more than 8 billion by 2030—the urgency of water security will multiply.

Global Water Trends of Concern

Increasing demand, degraded supply, uneven distribution, and aging infrastructure are a few of the issues affecting water security, that is, the capacity of a population to ensure that they continue to have access to potable water. Global climate change is projected to impact both the supply and distribution of water. Most of the world's water is shared by several countries and the potential for conflict is real. Army installations located overseas are subject to the same resource pressures as their host countries. It is imperative that installation staff be aware of water vulnerability issues that could impact sustainable future supplies.

Increasing global demand

The driving forces and pressures on water resources include both naturally occurring and human actions. Human related driving forces include population growth, demographic change including migration from rural to urban areas, increase in standard of living, competition between users, and pollution of water resources. The natural variability of climate-induced distribution and occurrence of water make it difficult to predict the resource. One forecast presents a "business as usual" demand in 2030 of 6900 billion m³. This compares to current global use of 4500 billion m³ (1.2 trillion gal) and is 40 percent above current, accessible, reliable supply (2030 Water Resources Group 2009).

* The Millennium Development Goals are eight international development goals set in 2001 that all 192 United Nations member states have agreed to achieve by the year 2015.

The Food and Agricultural Organization of the United Nations (FAO) publishes periodic reports on the status of total actual renewable water resources (TARWR). TARWR is a volume expressed in km³/yr that is calculated for individual countries using population, precipitation, surface and groundwater, and incoming and outgoing waters. As an example, the United States consumes 16 percent of its TARWR while the United Arab Emirates consumes 1.538 percent of its TARWR, meaning that it is a net importer of water. Data is also available through the main AQUASTAT country database on their website* (Aquastat 2010).

Groundwater depletion

Groundwater represents the largest source of fresh water in the hydrological cycle, about 95 percent globally. Groundwater quality and quantity are threatened by human activities that exert pressures on the environment including urbanization, tourism, industry, and agriculture. As an example, more than two-thirds of Europe's population lives in urban areas and the rate of urbanization is increasing in Central and Eastern Europe. Industrial pressures include demand for cooling and cleaning, pollution with potentially toxic inorganic and organic substances, disposal or dumping of sludge and waste, inadequate containment of old industrial sites, accidents during production and transport, and harmful air emissions—mainly from the combustion of fossil fuels—that lead to acidification. Tourism increases water demand pressures during seasons when supply may already be critical. Agriculture is the main source of non-point source pollution, hence, is very difficult to control.

Over-abstraction of groundwater depends on the source, the climate, hydrological conditions, and the uses of the water. The expansion in groundwater abstraction over the past 30–40 years supported increased agriculture and development in regions where alternative sources were more expensive or not available. The effects of over-abstraction are: groundwater depletion, saltwater intrusion, loss of habitats, subsidence, and changes to the surface water system due to groundwater-surface water interactions.

Global climate change

Water availability is subject to the impacts of global climate change. Global climate change is projected to have a variety of effects on the water cycle including reduced supply reliability, increased flood risk, impaired health,

* <http://www.fao.org/nr/water/aquastat/main/index.stm>

increased agricultural requirements, increased needs for energy production and generation, and changing aquatic systems. The main climate drivers that affect water are changing temperature and precipitation and rising global sea levels (Brekke et al. 2009). Specifically, increasing global temperature has the immediate effect of producing higher evaporation rates, thereby drying soils, increasing irrigation requirements of agriculture, and reducing reservoirs of surface water. Aquifer recharge will also fall, accelerating groundwater depletion.

A range of changes to weather patterns are anticipated. These include both increased flooding and drought as storm events become larger and more seasonal. Fresh water supplies are expected to decrease and become vulnerable to salinization. Reduced snowpack and glacier melt is expected to diminish surface water availability for seasonal demands (McKeown and Gardner 2009). The US Geological Survey's study of middle latitude, high-mountain glaciers is being affected by the disappearance of some due to global warming (Cecil et al. 2010).

Many of these impacts are already occurring, and affect the poorest people and countries the most. Availability of water in "mega-cities," home to 10 million or more, is already an issue of concern. The most damaging effects are the impacts of extreme events (high intensity cyclones and storms) rather than increases in the average climate variable. The combination of intense storms and sea level rise place coastal communities at increased vulnerability worldwide (International Alliance of Research Universities 2009).

The right to water

Conflicts over water date from circa 2500 BC when the King of Lagash diverted water to boundary canals to deprive neighboring Umma of water. The Pacific Institute's Water Conflict Chronology contains over 200 entries encompassing control of water resources, water used as a military tool, water used as a political tool, water as a target of terrorism, water as a target of military actions, and disputes over water in the context of economic and social development (Gleick 2008).

Modern disputes are legion: between the United States and Mexico over the Colorado River, between India and Bangladesh over the Ganges and Brahmaputra Rivers, between China and neighboring Southeast Asian states over the Mekong River, and between Egypt and Ethiopia over the Nile River (Nickum 2010).

Most of the large non-renewable reserves of groundwater are shared. Lack of data about both groundwater level and quality make both development and management difficult. A database of shared groundwater resources is being compiled by the United Nations Educational, Scientific and Cultural Organization (UNESCO) through the Internationally Shared Aquifer Resources Management (ISARM) project.*

Almost half of the Earth's land surface lies within international river basins. These assets are managed within the framework of international treaties and agreements. UNEP has documented the world's international basins and agreements (Figure 1) with both a graphical and textual context in the Atlas of International Fresh water Agreements (UNEP 2002). Additional resources include the Transboundary Fresh water Dispute Database, FAO's legislative database, FAOLEX, and the joint UNEP, IUCN, and FAO gateway to environmental law, ECOLEX. These references improve understanding of existing treaties and of the treaty development process and support development of new treaties.

UNESCO also sponsors the From Potential Conflict to Cooperation Potential program (PCCP). Housed within the International Hydrology Program, the PCCP provides support where water users need to manage their shared water resources in a peaceful and equitable manner. There is a focus on tools to anticipate, prevent, and resolve water conflicts.†

Energy and water

The energy-water nexus dates back to the use of water wheels to produce mechanical energy. Water is critical to energy production yet the impact of energy on water is often overlooked. Approximately 8 percent of fresh water withdrawals globally are used for energy (World Economic Forum and Cambridge Energy Research Associates 2008).

Increasing water demands for energy, prompted by population growth and economic development, are poised to collide with a finite water supply already subject to degradation and vulnerable to climate change. How we plan—or fail—to resolve the competition between water and energy needs will become one of the defining issues of this century (IEEE 2010).

* <http://www.isarm.net/>

† <http://www.unesco.org/water/wwap/pccp/>



Figure 1. Map showing European basins and treaties (UNEP 2002).

Water is required in the extraction, transformation, and delivery of energy. Some of the end uses of water include pumping crude oil, removing exhaust gas pollutants, generating steam, flushing away combustion residue of fossil fuels, and thermoelectric cooling. Tables 1 and 2 quantify the water requirements of a range of fuel sources and of different types of electric power generation.

Water withdrawals for energy exceed consumption by as much as 25 times in the United States. However, absolute withdrawn water is important for two reasons. First, the water must be available for smooth operation of energy production, even though a small percentage is used consumptively. A second factor is that water used in energy industries is not always returned to the ecosystem in the same state in which it was withdrawn.

Water is also required for many renewable energy technologies. Hydropower, biofuel feedstock, biofuel production, geothermal power, and concentrating solar power demand water, and even photovoltaics require some amount of water to clean solar cells. Carbon capture and storage (CCS) technologies also have water needs.

Table 1. Water requirements of fuel sources (Jones 2008).

Fuel Source	Efficiency (L/1000 kWh)
Natural Gas	38
Synfuel: coal gasification	144-340
Tar sands	190-490
Oil shale	260-640
Synfuel: Fisher-Tropsch	530-775
Coal	530-2300
Hydrogen	1850-3100
Liquid natural gas	1875
Petroleum/oil-electric sector	15,500-31,200
Fuel ethanol	32,400-375,900
Biodiesel	180,900-969,000

Table 2. Water requirements by type of electricity generation (Jones 2008).

Power Generation Technologies	Efficiency (L/1000 kWhrs)
Hydroelectric	260
Geothermal	1680
Solar thermal	2970-3500
Fossil fuel thermoelectric	14,200-28,400
Nuclear	31,000-74,900

Globally, many countries are exploring the impact of substituting biofuels for transportation fossil fuels. This includes the setting of targets by the United States and the European Union. Worldwide fresh water use for agriculture is approximately 86 percent. Increasing biofuel production requires careful consideration to avoid conflict with the need for food and fiber. The impact on water resources of increased biofuel production depends on the feedstock selected and the region where it is grown, that is, whether it requires irrigation. Potential impacts of increased biofuel on water quality include nutrient pollution due to fertilizer runoff and sedimentation due to soil erosion. Selective agricultural practices, alternative water sources, and technology innovations can mitigate the effects of biofuel production on water resources. Improved crop varieties and careful location of biofuel production facilities—close to sustainable water resources—are additional considerations (Gerbens-Leenes et al. 2009).

The Army's renewable energy goal is to achieve 5 percent of total electric use from renewable sources by 2010, one that is unlikely to be met, while the Department of Defense seeks 25 percent renewable by 2025 (Smith et al. 2010). Some renewable energy options require little, if any water. However, the water requirements should be considered for each renewable energy development.

Overseas Army water challenges

Army installations are vulnerable to the same issues of water supply and demand that jeopardize global water security. Providing the required amount of clean fresh water in the location where it is needed is increasingly difficult. The complexity of local, regional, national, and multi-country regulatory regimes compounds the challenge. Local technologies and the language barrier are additional obstacles. In the coming years, the impacts of water scarcity will be more severe and this will be reflected in increasing costs. The circumstances that exacerbate water availability are the aging condition of water infrastructure, generalized population growth, changing demographics, increased demand of the energy sector, and uncertain, but generally agreed on regional impacts of global climate change.

Another complicating factor is that water recognizes no boundaries—installation, municipal, regional, or national—other than its own, that of watershed or sub-surface aquifer. Man intervenes in the natural hydraulic systems through inter-basin transfers, the movement of “virtual water” from one water region to another in products, construction of man-made water systems (levees, canals, etc.), and the increase in water bottling plants and other high water use industries. Planning for water sustainability is a regional issue requiring cooperation among a host of players whose decisions affect long-term scarcity:

- *Local Policies.* Obtaining information about local policies related to water supply and demand can be difficult at an overseas site. The hierarchy of water regulation can be complex and have more layers than in the United States. For example, European countries must all comply with the European Union-generated directives, in addition to any national, regional, or local requirements.
- *Politics.* Regional politics can be a strong factor in any decision related to an Army installation overseas. Even infrastructure considerations must be weighed against the value of maintaining good will and cordial local relationships. Decisions related to sourcing new water requirements at overseas sites seemed to have been made with politics rather than cost in mind.
- *Availability of Local Data.* It is often difficult finding online sources of related data, as is possible in the United States. Even basic data, such as census trends and projections, were not readily available. Although at the installation and smaller regional level, availability of metering data is the same as in the Continental United States (CONUS), access to broader country data is limited. In other words, there was a lack of broader regional data: climate, specific water use, how water region is defined, e.g., smaller basin data were difficult to obtain in Italy and Korea.

- *Use of Locally Available Technologies.* There is sometimes a conflict between technologies that are “state of the shelf” in the United States and those deemed appropriate overseas. Use of local versus US technologies can ease procurement and maintenance. Local technologies are sometimes more advanced than their US counterparts, for example, water efficient technologies have been standard practice in Germany for decades. It can be difficult to know the water efficiency rating of a technology in the absence of labeling requirements, which is often the case.
- *Communication.* The language barrier is an obstacle to conducting water assessments overseas, and indeed, to managing an effective water conservation program at an overseas installation. Most local studies and data sources are available only in the native language. The ability to locate and understand local/regional data and information heavily depend on the ability of local national employees to translate to English. In one instance, incorrect information about the installation’s local water source was conveyed by DPW staff due to a language misunderstanding. The study team was unable to meet with local officials at two of the three overseas sites due in some part to the language barrier. Translation of documents would be easier with the use of a professional level translation tool, rather than using Internet translation websites.
- *Metering Program.* The Energy Policy Act of 2005 requires installation of building level water meters in all covered facilities by 2016. These facilities are defined based on size and/or water use. The meters are automated and will be connected to a central system for remote reading. Presently, it is typical that an installation only meter water at the point of delivery. Reimbursable customers will sometimes have utility meters although their use is often estimated.* At least one study installation discovered that they were under billing by half once they installed water meters.
- *The Army Military Construction (MILCON) Process.* Each overseas study site was selected due to the planned growth at the installation. The MILCON process is lengthy and time consuming for those unfamiliar. Incorporating the most appropriate and efficient water-consuming technologies requires action at specific points in the planning process. Installations sometimes take delivery of brand new buildings that could have been made more water efficient with little to no extra cost.

* From AR 420-41, Acquisition and Sale of Utilities Services: The purchaser will pay to install a meter at a new or existing point of delivery when the utilities sales officer determines that a meter is required. Army and Air Force Exchange Service and other NAF activities that pay for service will be metered, if practical, when the annual use is estimated to be more than \$360.

3 European Theater Case Study

Water trends of concern

Europe has been largely immune to severe water shortages until recently. Water scarcity has reached the critical level in many areas due to over-abstraction and extended droughts. Impacts of water scarcity are seen in reduced river flows, lower lake and aquifer levels, and drying up of wetlands. Water quality degradation usually follows diminished resource level. The impacts of projected climate change in Europe will most likely intensify these impacts due to increased droughts (EEA 2009).

Water quality

Historically, European water quality has been compromised since the Industrial Revolution when rivers were used as conveyance for waste to the sea. Recent decades have seen improvements in treating sewage and industrial waste that finds its way into the river systems. The Water Framework Directive (WFD), adopted in 2000, requires integrated water management planning in river basins based on a combined approach of water quality standards and emission limit values. The main water quality challenge remains non-point source pollution from agriculture. Pollutants that have been reduced include phosphorus and organic matter from industry and households, heavy metals, and oil spilled from vessels. Nitrate and pesticide pollution remains high, particularly in countries where agriculture is most intensive. In general, there are specific water quality problems and geographical “hot spots.”

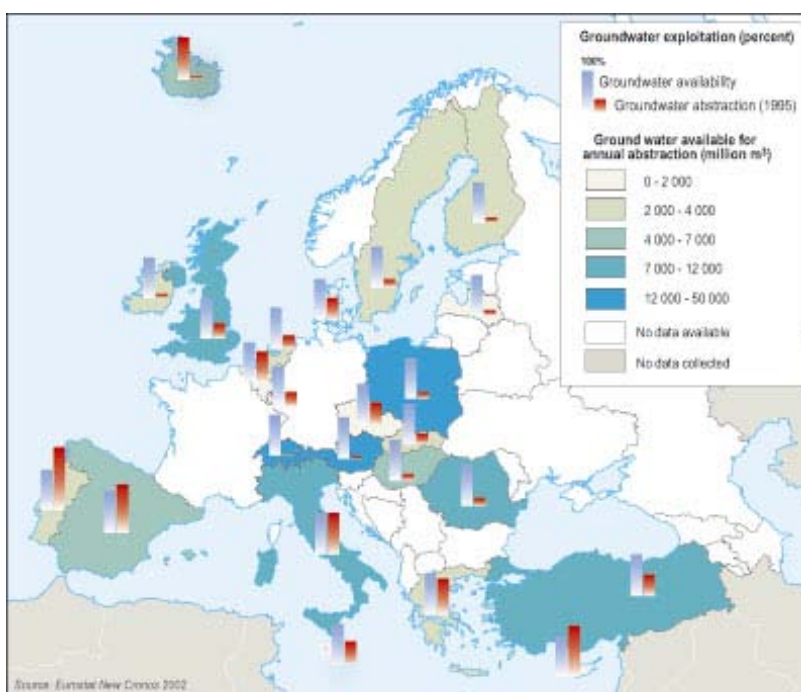
Transboundary waters

There are 150 major transboundary rivers in Europe that form or cross borders between two or more countries, some 25 major transboundary lakes, and some 100 transboundary aquifers. The numbers of international basins and the borders they cross, change with political changes. An example is the internationalization of several basins (Dnieper, Don, and Volga) with the breakup of the Soviet Union. Several international agreements cover the management of shared water resources in Europe. Although most shared water resources are included in transboundary agreements, disputes still exist. These can be related to seasonal water shortages, dam construction, pollution, and border disagreements as water bodies often serve as international borders.

Groundwater depletion

Groundwater depletion, which is a long-term decline caused by sustained groundwater pumping, is of great concern in many areas of Europe. Negative impacts of groundwater depletion include lowering of the water table, increased pumping costs, reduction of water in streams and lakes, land subsidence, and deterioration of water quality due to saltwater intrusion.

Figure 2 shows the annual abstraction rate for European countries along with the groundwater exploitation percent. Saltwater intrusion already affects large areas of the Mediterranean coastline of Italy, Spain, and Turkey due to over-abstraction for public water supply. Irrigation is the cause of over exploitation in the Greek Artgolid plain of eastern Pelopponnesos, where boreholes as deep as 400 m (1312 ft) are contaminated by saltwater intrusion. Ground subsidence and soil compaction are impacts of heavy draw-down along the Veneto and Emilia-Romagna coasts, the Po delta and particularly in Venice, Bologna, and Ravenna in Italy (UNEP/DEWA, 2004).



source: www.reports.eea.europa.eu/groundwater

Figure 2. European groundwater resources and exploitation (UNEP/DEWA, 2004).*

* Data for groundwater resources are long term annual average; data for groundwater abstractions refer to year 1995 except for Cyprus 1998, Ireland 1994, Netherlands 1996, Portugal 1998, Italy 1985, and Turkey 2000.

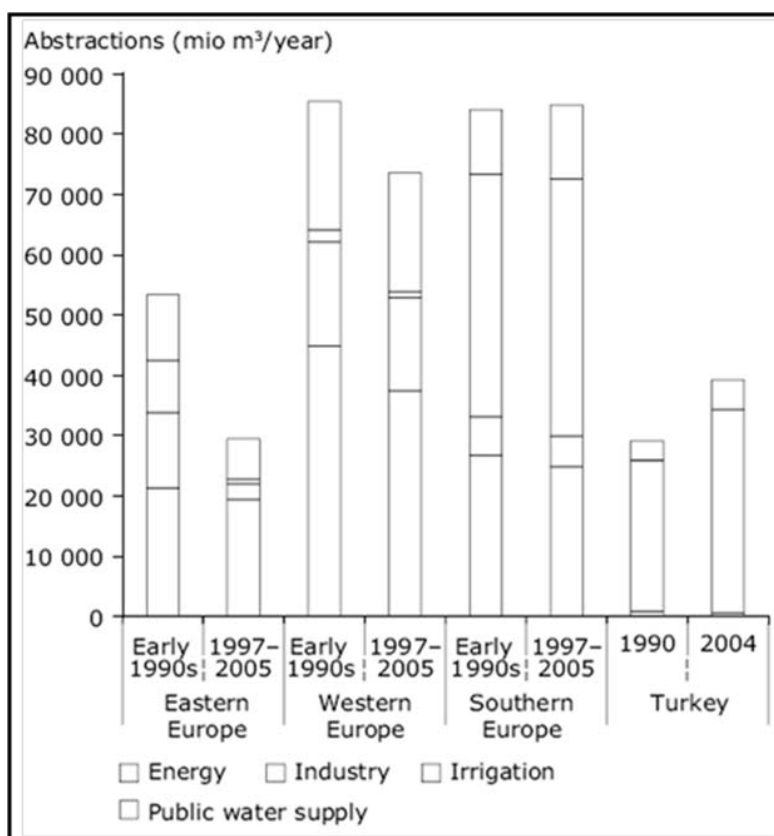
Separate from over-withdrawal and misuse, climate change will almost certainly exacerbate human impacts on water supply. It will likely cause more severe and unpredictable weather patterns across Europe as civilization struggle to maintain their current water supply and standard of living.

Since Europe has 13 percent of the world's population, but only 8 percent of the world's resources of fresh water, over-withdrawal in arid Mediterranean regions of Europe have increased the risk of desertification in the southern parts of Europe. Some environmental groups estimate up to 60 percent of Spain and 30 percent of Italy, including the fertile northern Po river region, are susceptible to desertification.

Problems of water scarcity arise in many regions due to an imbalance between withdrawal and availability. For example, two-thirds of the agriculture productions of the European Union (EU) are concentrated in the arid regions of southern Europe. Here, as mentioned above, agriculture accounts for more than half the total national withdrawals, rising to more than 80 percent in some regions. Reliance on tourism can markedly increase public water use, particularly during the peak summer holiday months and especially in southern European coastal regions already subject to considerable water stress. For example, in 2006, Spain increased its number of golf courses from 308 to 324. Despite its water stressed resources, 65 percent of these golf courses are located in arid regions of the country (CafeBabel). In addition, countries that heavily rely on tourism must account for increased water use for food, drinks, personal hygiene, and activities such as swimming.

Rising demand for water

Public water supply in Eastern Europe has declined since the early 1990s due to the introduction of metering and higher water prices. Recent economic growth in Eastern Europe is, however, predicted to reverse the overall downward trend in the future. A similar (but less marked) reduction in supply is apparent for Western Europe over recent years, driven by the implementation of water saving measures. Southern Europe has maintained consumption levels (Figure 3). The Water Exploitation Index (WEI) shows available water resources compared to the amount of water used. An index rating over 20 percent usually denotes water scarcity. Figure 4 shows nine countries that are considered water stressed: Belgium, Bulgaria, Cyprus, Germany, Italy, the former Yugoslav Republic of Macedonia, Malta, Spain, and the United Kingdom (England and Wales).



source: EEA 2007

Figure 3. European water use trends.

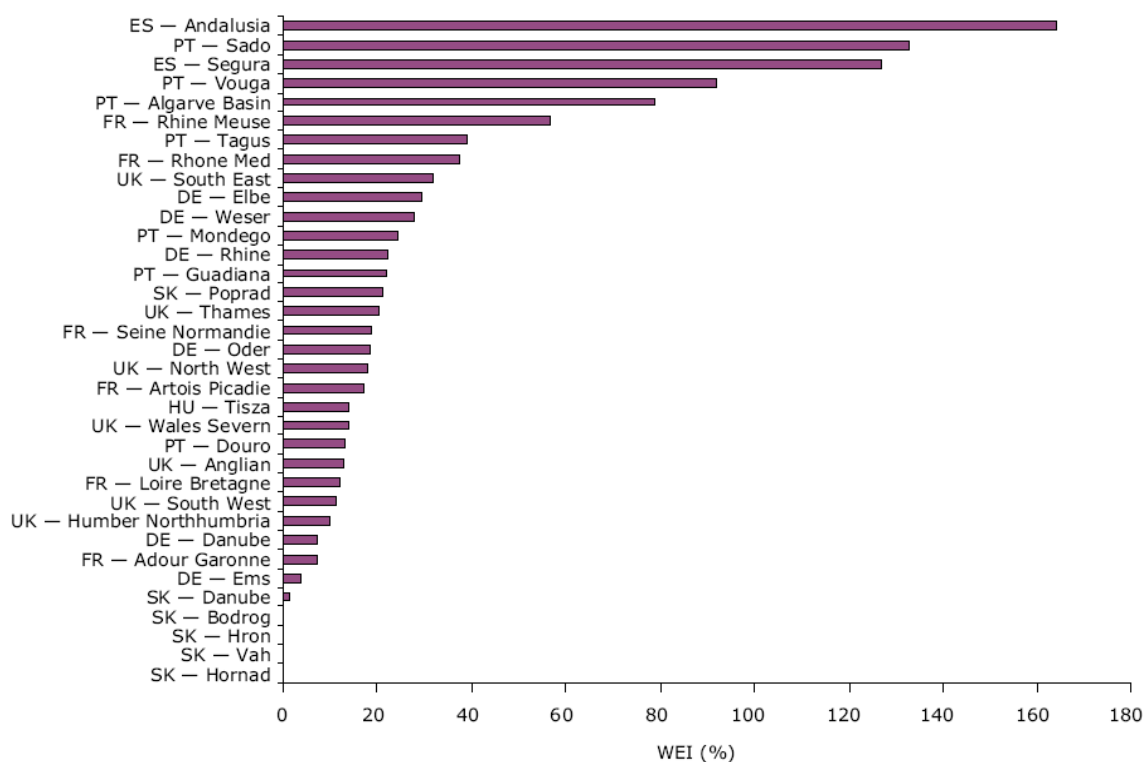
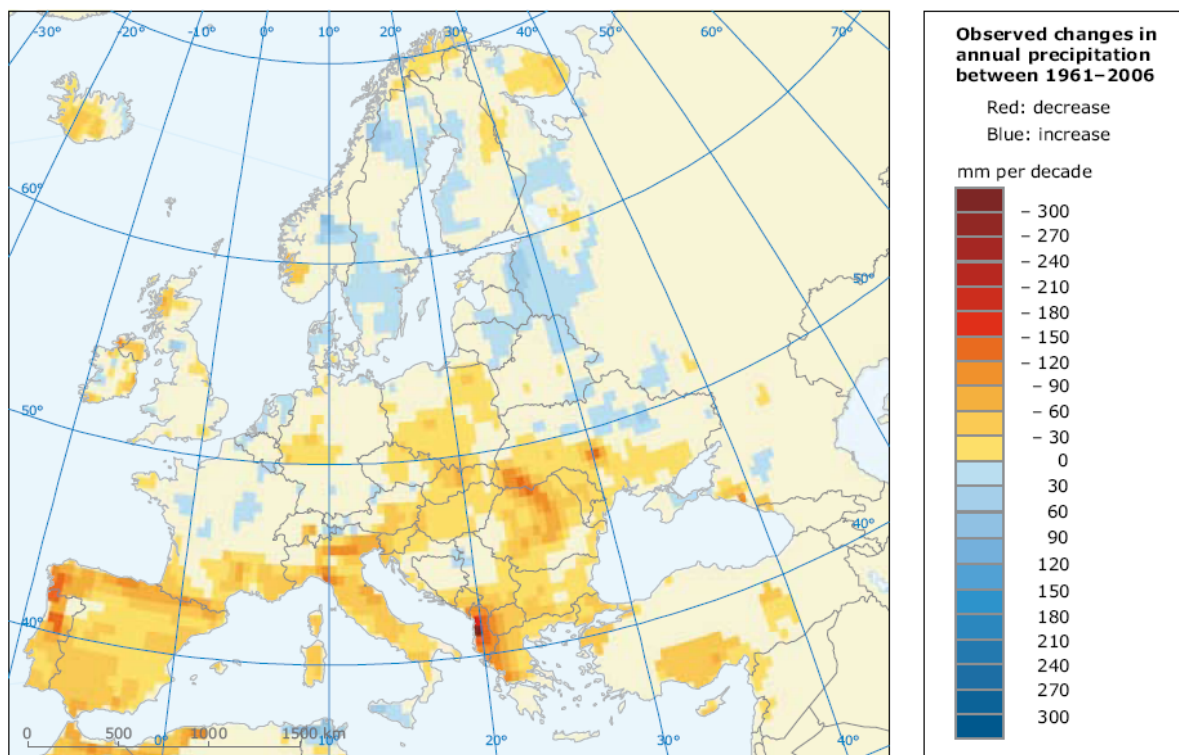


Figure 4. Water exploitation index.

Currently the EU has an estimated population of 556 million inhabitants. As a whole, that number is expected to grow through the coming decades despite some the population decline in such individual countries as Germany and Italy. Countries in Eastern Europe are expected to grow in population as their economies develop. Geographic regions of concern in terms of water availability include southern Europe where populations are expected to continue to grow until 2020 and eventually Eastern European countries as their demand rises with their standard of living.

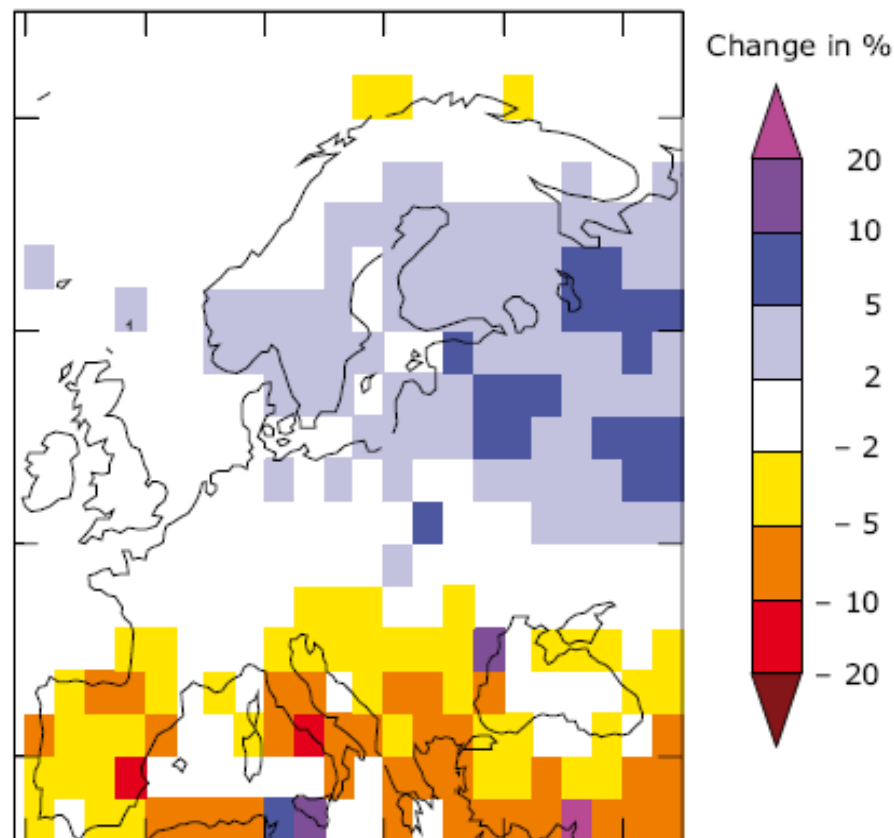
Climate change

There are large geographical differences in terms of precipitation; however, there is a notable reduction in the Mediterranean and eastern Europe, while increases have occurred along the Atlantic shores from France to Norway as well as in the Alps and northeastern extensions (Figures 5 and 6). Climate models predict a general future increase in precipitation in northern Europe and a decrease in southern Europe. Seasonally, a large increase in winter precipitation is predicted for mid and northern Europe, while many parts of Europe are expected to experience drier summers (EEA 2008).



Source: ENSEMBLE, <http://www.ensembles.eu.org> and ECA&D, <http://eca.knmi.nl>

Figure 5. Precipitation trends.



Source: Milly et al. (2005).

Figure 6. River flow trends.

Flooding

The EU's Energy, Environment, and Sustainable Development Program predicts a general decrease in precipitation in the future in southern Europe, but an increase in northern Europe. Thus, the dry regions of southern Europe are projected to become drier, while northern Europe continues to battle flooding. In the past 7 years Europe has suffered over 100 major floods. The most recent severe flood, along the Danube River in June of 2009, affected Austria, Hungary, the Czech Republic, and Poland, causing several deaths (Associated Press). In 2002, a 100-year flood affected most of Europe and caused dozens of death. Flooding was so widespread it motivated several countries to re-assess their flood mitigation policies. Studies that followed this flood confirmed that increased precipitation, changes in river management (such as river course adjustments and deepening), and increased urbanization in riparian zones had exacerbated the flooding trends (EEA 2007).

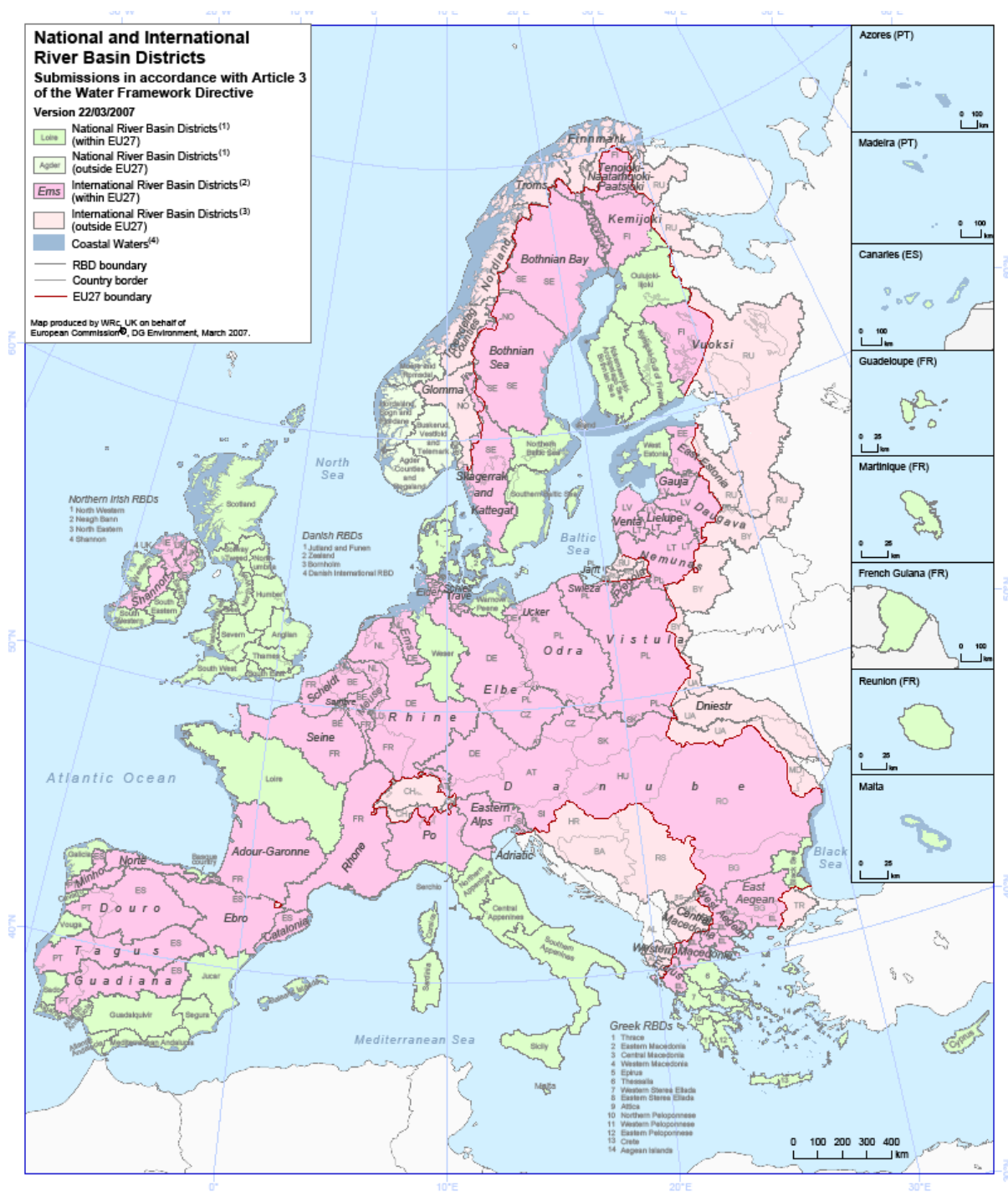
European water policy

The European Commission (EC) recognized that many of the major rivers and basins are cross-national and thus, wide coordination was needed to make water management truly effective. In 1995, the EC directed creation of a directive that could legally address and coordinate water problems within Europe. By 2000, the EU established and adopted into policy the Water Framework Directive (WFD), more formally referred to as the “Directive 2000/60/EC of the European Parliament and the Council of 23 October 2000” establishing a framework for Community action in the field of water policy. The WFD provides a holistic water management approach across Europe, addressing water needs and standardizing each country’s water policies. Four other pieces of EU water legislation remain in place with the WFD:

- The Urban Waste Water Treatment Directive
- The Bathing Water Directive
- The Nitrates Directive
- The Drinking Water Directive.

The WFD directive is the most significant piece of European water legislation in that it introduced a statutory system of analysis and planning based on the river basin (Figure 7). International river basin districts (RBDs), classified by the EU, define boundaries under which nations must work in concert with one another to complete their analysis of each RBD, whether partially or wholly within their national borders. The member nations must review the impact of human activity on the water resources and then perform an economic analysis of water usage within each RBD to further assess economic impact on their resources. They must also compile a register of areas requiring protection and present their results to the EU as part of the process and results.

According to the WFD, by 2004, each member nation was to have adopted the WFD into their national policy and set up legislative tools for its management. By 2009, each country as to have a water management plan and program of measures produced for each RBD. And finally, by 2015, each country should have enhanced and restored water bodies to a “good” status through the process of protecting groundwater sources, preventing pollution, and ensuring a balance between groundwater withdrawal and replenishment. As members of the EU, each country is bound to abide by the directives provided by the EU commission or risk legal actions and fines (EU Directive 2000/60/EC).



Footnotes:

- 1) Map based largely on submissions of digital River Basin Districts (RBDs) from EU Member States and Norway.
 2) Some of the international RBDs shown on this map were not identified as being international by the Member

- 3) These are the boundaries of the river catchments extending beyond the EU27 border. They have been derived from the Catchment Characterisation and Modelling (CCM) database, developed by the Joint Research Centre (JRC), except the boundaries for the Danube

Source: Map produced by WRc, UK on behalf of European Commission, DG Environment, March 2007

Figure 7. WFD river basin districts (RBD).

To further promote stewardship, in 2009, the EEA called on European countries to change their water use habits to curb their demand or face further environmental degradation. Several recommendations were made to help shift the trend of increasing water problems. EEA Water Management Suggestions (2009) consist of:

- In all sectors, including agriculture, water should be priced according to the volume used.
- Governments should implement drought management plans more extensively and focus on risk rather than crisis management.
- Water-intensive bio-energy crops should be avoided in areas of water scarcity.
- A combination of crop selection and irrigation methods can substantially improve agricultural water efficiency if backed up with farmer advisory programs. National and EU funds, including the European Union's Common Agricultural Policy, can play an important role in promoting efficient and sustainable water use in agriculture.
- Measures to raise public awareness, such as eco-labeling, eco-certification, education programs in schools, are essential to realize sustainable water use.
- Leakage in public water supply systems must be addressed. In parts of Europe, water loss via leakage can exceed 40 percent of total supplies.
- Illegal withdrawal of water, often for agricultural use, is widespread in certain areas of Europe. Appropriate surveillance and a system of fines or penalties should be put in place to address the issue.
- Authorities should create incentives for greater use of alternative water supplies, such as treated wastewater, graywater, and "harvested" rainwater to help reduce water stress.

Germany overview

Germany's geography stretches from the Alps in the south, across the North European Plain and to the North and Baltic Seas. In area it is about 357,000 km² (140,000 sq mi), slightly smaller than the state of Montana. There are three parallel landscape types: the North German Lowlands, Central German Uplands, and Alpine region (which consists of the South German Alpine foothills and the Bavarian High Alps). The northern third of the country consists of flat terrain crossed by northward-flowing rivers (the Elbe, Ems, Weser, and Oder). The border with the Netherlands and along the Frisian coast contains wetlands and marshy conditions. The northeast contains many lakes formed by glaciation. The hills of the Central Uplands separate North Germany from South Germany. The Uplands

contain mountainous regions and valleys, with mountains ranging 700 to 1500m. Southern Germany is hilly as well and contains the Bavarian and Black Forests, along the east and southwest borders, respectively. Although the Alps define southern-most Germany, very little Alpine terrain lies within Germany.

Germany is among the largest agricultural producers in the European Union. More than half of Germany's territory is used for farming. One-third is arable land with one percent in permanent crops. Meadows and pastures comprise 16 percent and forest and woodland 30 percent. All other land uses total 19 percent (Federal Ministry of Food, Agriculture and Consumer Protection, 2010).

Climate

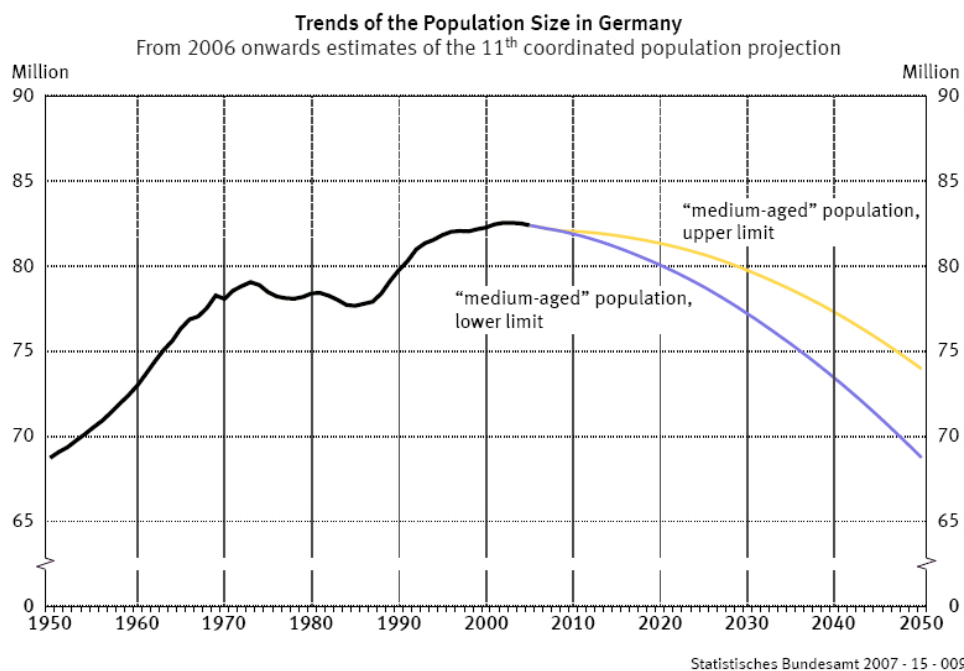
Germany's climate is classified as humid temperate and seasonal. In the northwest and north the climate is moderated by the North Atlantic Drift causing year round rainfall with higher amounts in the summer. There are major regional variations in the quantity of precipitation, which ranges from 2450 mm (96.5 in.) per year in Balderschwang in Algau to 417 mm (16.4 in.) in Artern in Saxony-Anhalt. This reflects the general trend in precipitation, which declines from west to east. Winters are mild and temperatures tend to be cool. Eastern Germany has greater temperature extremes with colder winters and warmer summers. Central and southern Germany are transitional regions between the two climates. The summer of 2003 was the hottest in Germany since 1901, 3½ °C warmer than average.

Demographics

Germany's population officially decreased for the first time in 2003 (Figure 8). Germany's Federal Statistics Office (GFSO) expects this trend to continue as Germany's numerically dominant elder generation continues to age. Current forecasts project Germany's population to be between 69 and 74 million by 2050 (German Federal Statistic Office 2006).

Water resources in Germany

Germany has an extensive river system with about 400,000 km (248,560 mi) of rivers and streams. There are over 7500 km (4660 mi) of flood protection dykes and protection walls and over 500 impounding dams and large retention basins. These combine to form a flood capacity of 1 billion m³ (264 trillion gal) (EEA Environmental Issue Report 21 2001).



source: German Federal Statistics Office
Figure 8. German population projections.

Germany's total renewable volume of water is 188 km³ (41.4 trillion gal), of which 20 percent is withdrawn per year (Gleick 2009). Germany's water supply is generally adequate due to its location in northern Europe and its temperate climate. When Germany experiences drought, it is rare, seasonal, and regional in scope.

Germany's public water service is considered one of the best in Europe, with connection rates estimated at 99 percent and a competitive regional pricing system that achieves almost full cost recovery of services to consumers, thereby avoiding subsidizing (Kreamer 2007). The combination of Germany's pricing, public awareness, and technologically advanced water system help to rank it second to Italy in water consumption. For example, Germany on average withdraws about 460 m³ (121,532 gal) per year compared to Italy's 723 m³ (191,017 gal), although Germany has up to 40 percent more fresh water available than Italy. Public awareness, as displayed through average per capita consumption, demonstrates how Germany can withdraw 38.1 km³/yr (8.4 trillion gal) compared to Italy's 41.98 km³ (9.2 trillion gal), despite having 24 million more inhabitants.

The combination of the technological upgrades, public awareness, and a declining population has enabled Germany to reduce its water usage. Current water demand for private households is 15 percent below the 1991 demand, and water withdrawal for cooling purposes for power stations has

also declined by 29 percent over the same period (EEA 2005). Data from 1991 to 2004 show per capita water consumption dropped from approximately 148 to 127 L/day (33.6 gal/day). Demand in some locations has decreased enough to allow water in the pipes to become stagnant, requiring systematic flushing of the piping systems. For further reductions, Germany may have to remove or cap connections to avoid wasting water for routine systems flushes. Capping may become an eventual necessity to economize Germany's existing infrastructure as its population is projected to continue to decline (Hummel 2007).

Expected impacts of climate change

As a result of climate change, floods are more of a concern in Germany due to the extensive river systems and growing urbanization within riparian zones. Recent floods throughout Europe are causing mounting concern because of their increasing frequency and the high level of monetary damage they incur. The most recent severe flood event to hit Central Europe, including Germany, occurred in 2002 along the Elbe and Danube rivers. The 2002 flooding caused 21 deaths in Germany alone and over 10 billion Euros in damage across the country, with 198 million in the state of Bavaria (Theiken et al. 2007). As a result, in 2005, Germany adopted a new national policy to address means to mitigate further heavy floods and flood damage. Nevertheless, the responsibility for flood and water policy development and implementation resides with the individual German Federal states and not with the central government. As a consequence, given the different geographical circumstances, different levels of flood hazards and risks in each of the Federal states, and also different philosophies regarding flood protection, the activities in flood protection policy and flood damage analysis vary significantly.

Water policy in Germany

Less than 2 months after the EU enacted the WFD, Germany adopted the general intent of the Directive into its national Water Act policy, but due to constitutional restrictions, the Federation was only able to enact "skeleton provisions" of the WFD at a Federal level (LAWA 2003). For actual regulatory implementation and compliance, the WFD relies on the individual German states (Figure 9) to adopt the ordinance and incorporate procedural provisions into law. As a matter of administrative efficiency to facilitate each state's compliance to the WFD, the Landerarbeitsgemeinschaft Wasser (LAWA) (made of member state water directors) has developed guidance for states to follow.



source: Bavarian State Ministry of Environment and Health

Figure 9. German water management offices.

Coordination by LAWA has helped Germany abide by most of the EU's Directives. However, some eastern German states were slow in their implementation of the WFD, thus allowing the EU Commission to accuse Germany of infringing on its obligation to completely adopt the Directive by 2004. Germany has since resolved its case and has since met the EU's WFD requirements. Germany has generally applied the policies—albeit sometimes with incomplete data—and addressed the data analysis requested by the EU to comply with the deadlines. Due to its industrial pollution, the status of about half of Germany's groundwater bodies is expected to fall short of the target status of “good” by 2015, as established by the EU (Bosc hek 2006).

US Army Garrison Grafenwoehr

Within this study, US Army Garrison Grafenwoehr (USAG-G) refers specifically to the garrison sites of Main Camp Grafenwoehr and Netza berg Community. USAG-G has the mission of supporting and enabling the readiness of its tenants, including the 7th Army Joint Multinational Training Command, the 2nd Stryker Cavalry Regiment (SCR) and North Atlantic Treaty Organization (NATO) units, to facilitate deployment operations, and assist staging operations. This includes power projection, force protection and Conventional Forces Europe (CFE) training and support, including live-fire training, engineering operations, air-drop exercises, helicopter gunnery and aircraft operations, and maneuvering. The garrison provides the highest quality training environment for the Army's European theater

of operations. Approximately 1840 local nationals are employed at USAG-G. The garrison population also includes 4014 military personnel; 1555 training troops (US and NATO members); 495 DoA civilian employees; 497 contractors; 129 retirees; and 6648 family members.

USAG-G is located among the hills in eastern Bavaria within the district Upper Palatinate in the county Neustadt ad Waldnaab. The area straddles the Danube and Elbe river basin districts. The garrison is bordered to the north by Thumbach stream and to the east by the Creussen River. Schaumbach Stream runs through the garrison and connects with Creussen River, which then connects to Haidenaab River and feeds into the Danube River. Despite the abundant surface water, 84 percent of the local water supplies come from groundwater.

The area surrounding USAG-G is mostly agricultural and is temperate in climate. It receives an average rainfall of 31.5 in./yr (800 mm/yr). The renewable water supply of local aquifers is 6879 m³/yr (1.8 million gal/yr). The Neustadt county uses only 84 percent of the total supply—5829 m³/yr (1.5 million gal/yr). Of the water used, 81 percent goes towards households and small businesses. The average water usage in the Neustadt ad Waldnaab per person per day is 131.2 L (34.7 gal). (BSOSD 2010).

Outside the garrison's gate is the city of the same name, Grafenwoehr, with a population of about 6900 persons. The surrounding county of Neustadt a.d. Waldnaab has roughly 99,000 people, whereas the larger district of Upper Palatinate has just over 1 million. Population forecasts for Neustadt a.d. Waldnaab follow the national declining trends; its population is expected to decrease to just fewer than 95,000 by 2025. Current population density in Neustadt a.d. Waldnaab is 69 residents per square kilometer (179 residents per sq mi).

Region of analysis

Figure 10 delineates the analysis region for the USAG-G water sustainability study. The region is defined by the aboveground hydrological catchment area (red boundary lines). The area spans approximately 400 km² (154 sq mi) bounded by the cities of Pressath, Eschenbach, and Grafenwoehr. USAG-G is located along the southern edge of this boundary. This boundary strictly includes the garrison sites of Main Camp Grafenwoehr and Netzaberg Community. The local water authority monitors aquifer conditions at the catchment area level. Thus, it is a logical choice in defining the region.

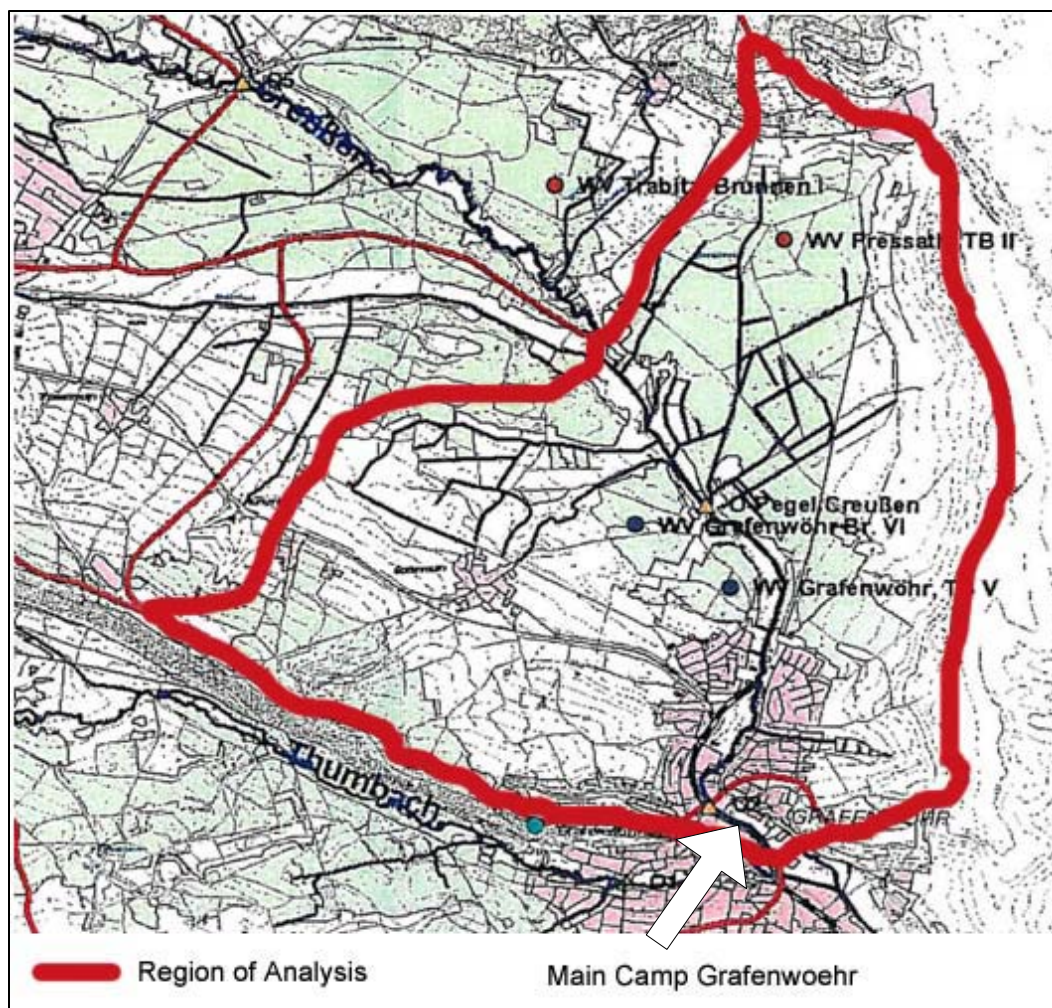


Figure 10. USAG-G region of analysis.

Regional water management factors

Like much of Germany, the study region has a very good record on water services. Water stress is rare due to low water consumption and high levels of supply. The following sections on water supply and demand will quantify these levels. On the whole, this can be attributed to the local regulatory structure. Local authorities routinely monitor local aquifers and establish sustainable abstraction levels. This regulation keeps users from over abstracting water resources. Furthermore, local authorities require water protection zones be maintained around all water sources.

USAG-G purchases the majority of its water from municipal suppliers. In cases of emergency, USAG-G maintains two groundwater wells on-post. These wells have the capacity to supply critical functions on-post. Because groundwater protection zones have not been established for these wells, potable water may not legally be withdrawn. Establishment of protection

zones would likely inhibit training capabilities. Thus, a cooperative relationship between USAG-G and its neighbors is essential to maintaining water supplies

Stadt Grafenwoehr hydrogeologisches modell für das einzugsgebiet “mittlere creussen” (Water supply model)

Groundwater supplied by seven wells is the sole source of water within this region. Under the German Water Act, water protection zones protect the quality and recharge of the wells. Figure 11 shows the movement of groundwater within the region. Figure 12 defines the water protection zones adjacent to USAG-G's fenceline.

Potable water for the Main Camp (including the Field Camps) is purchased from the city works of the city of Grafenwoehr under contract. The contract includes a minimum quantity of 500,000 m³/yr (132,086,026 gal/yr). From the fenceline connection point, a government owned supply line feeds the on-post pump station. The meter is located at the on-post pump station. From the pump station, the water is treated and pumped to a high level 450,000 m³ (118,877,423 gal) water reservoir located on the historic water tower.

Another main from the pump station supplies water to a 2000 m³ (528,344 gal) capacity elevated underground storage reservoir located close to range 118. This reservoir mainly supplies the field camps. Potable water for the Netzaberg Community is supplied by the city works of the city of Eschenbach. USAG-G maintains three wells on-post. The Range 301 well provides water to Range 301 and is owned and operated by the US Army. The water is chlorinated on-site. Well #5 and Well #6 are maintained as back-up supply only. Water from Well #6 is also used to irrigate the sports fields. Because groundwater protection zones have not been established for these wells, potable water may not legally be withdrawn.

Numerisches grundwassermodell eschenbach, Grafenwoehr

The county water authority monitors the local aquifer. The latest hydrological study was completed in 2004. Under guidance from the hydrological report, withdrawal allotments are assigned for each catchment area. Allowances are determined to be a sustainable abstraction level based on the aquifer conditions and the population needs.

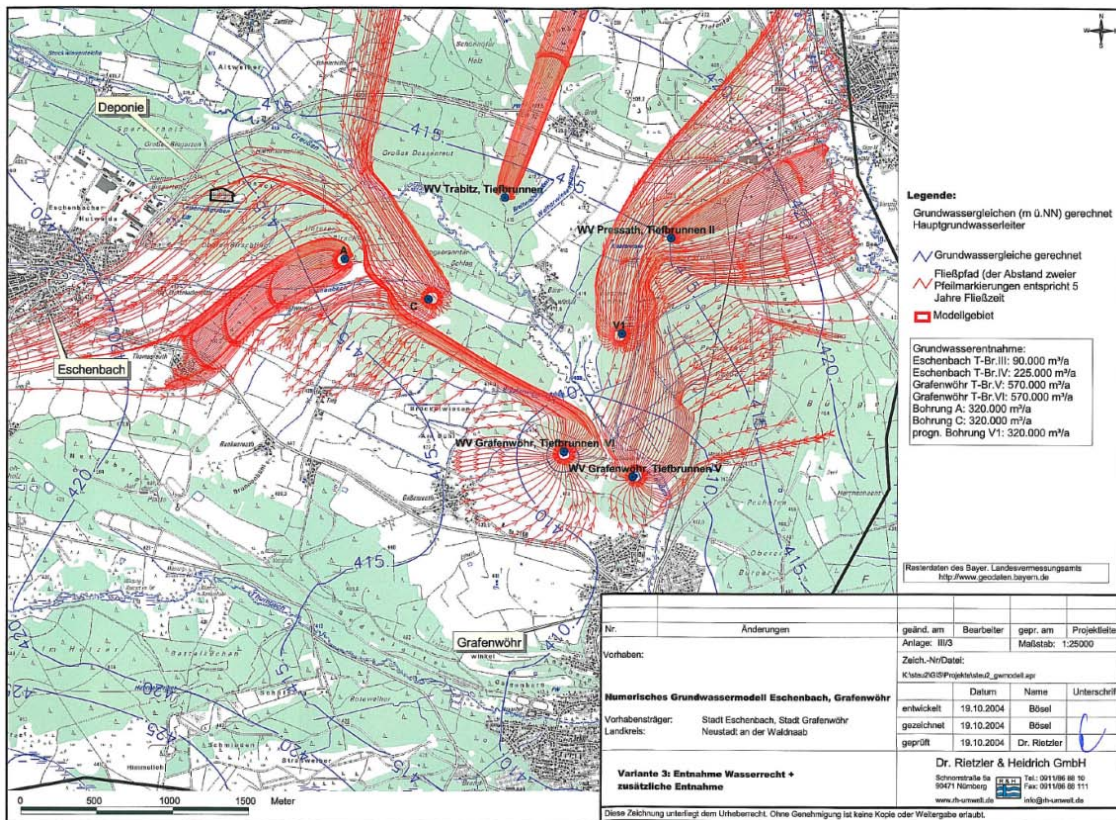


Figure 11. Groundwater Movement



Source: USAG-G Environmental Office.

Figure 12. Water protection zones.

The study catchment area is allotted a withdrawal allowance of 3.5 million m³/yr (924.6 million gal/yr). If the region desires larger allotments due to population or industrial changes, they must apply for the permit. Likewise, if climate or precipitation levels significantly change, the local authority can reduce the allotment. This analysis acknowledged the hydrological study and accepted the allowances as the sustainable supply capacity for the region. Table 3 lists groundwater supplies for the analysis region.

Supply factors

As discussed, the local authority has the ultimate control on maximum groundwater abstraction rates. Changes in climate, particularly precipitation, or quality protection zones can influence changes in water allotments. Scenario 2 reflects the potential impacts of a decrease in allowable withdrawal rates.

Water Demand model

The seven water supply wells serve a population of nearly 55,000 persons. Table 4 details this population. Local municipalities estimate a consumption rate of 110 L (29 gal) per capita per day. USAG-G estimates a consumption rate of 200 L (53 gal) per capita per day on-post. Loss in the distribution system is minimal. Overall, Germany reports a 7.3 percent leakage rate. Leakage is thought to be 1–3 percent within the study region.

Table 3. Groundwater supply.

Well	Location	Withdrawal Capacity* (m ³ /yr)	Withdrawal Capacity* (gal/yr)
#1	City of Pressath	0 (not in use)	
#2	City of Pressath	185,000	
#3	City of Eschenbach	90,000	
#4	City of Eschenbach	225,000	
#5	City of Grafenwoehr	500,000	
#6	City of Grafenwoehr	500,000	
#7	City of Pressath	500,000 (new authorization)	
Range 301	USAG-G	300	
#5	USAG-G	0 (emergency supply)(
#6	USAG-G	10,000 (irrigation and emergency supply)	
Total Maximum		2,010,300	
Maximum Allotment		3,500,000	
*maximum abstraction estimation based on local knowledge and pumping capacities			

Table 4. Regional demand.

Water User	Population	Water Demand**	Projected Population	Projected Water Demand***
	2010 persons	FY2009 MGD	2040 persons	2040 MGD
City of Pressath	4,600	0.13	4,600	0.13
City of Eschenbach	4,000	0.12	4,000	0.12
City of Grafenwoehr	6,900	0.23	6,900	0.23
USAG-G*	38,930	0.60	42,500	0.76
Total	54,430	1.08	58,000	1.38
USAG-G				
Family housing		0.3532		0.3924
Barracks		0.0836		0.2363
Dependent schools		0.0009		0.0013
Medical		0.0012		0.0012
Commissary		0.0015		0.0015
Ranges		0.0007		0.0007
Other installation operations		0.1833		0.2539
High water use facilities		0		0
Irrigated/improved land		0.0072		0.0072
Other uses		0		0
Losses		0.0027		0.0049
Army water efficiency program				-0.14
USAG-G w/efficiency (MGD)		0.6		0.76
USAG-G w/efficiency (CBM/yr)		822,283		1,043,950
<p>* Includes all population, i.e., military, civilian employees, family members, retirees, contract employees, and training troops for the study area sites (e.g., not Vilseck or Hohenfels)</p> <p>** Municipality demands estimated from conversation with Grafenwoehr Mayor and Stadtwerke water district manager. USAG-G demands estimated from Directorate of Public Works (DPW).</p> <p>***Reflect Army Water Efficiency Program (EO 13514) to reduce water consumption 2 percent annually through 2020. The 2 percent reduction was calculated for total water demand—including privatized family housing units.</p>				

The region abstracts approximately 1.5 million m³ of water annually (396.26 million gal annually). This rate is expected to increase slightly over the next 30 years to 1.7 million m³ (450 million gal). Despite the forecast decline in population within this timeframe for the county of Neustadt a.d. Waldnaab, the economic drive of the military will likely maintain municipal populations within the study region. Army transformations relocate the 2nd Stryker Cavalry Regiment to Vilseck (approximately 2000 soldiers) and the 172nd Infantry Brigade to Grafenwoehr (approximately 2500 soldiers) by the end of FY 2012.

This stationing initiative, known as Efficient Basing-Grafenwoehr (EBG), is a cost and time-saving measure realized by consolidating about 1400 wheeled and tracked vehicles, 4500 Soldiers and 6800 family members

that were spread over many widely dispersed locations into a single training area. A mature, well-exercised railhead system, a bulk fuel site, and excellent local training areas with immediate access to the Grafenwoehr Major Training Area are additional benefits.

Overall water use is highly efficient. The only expected change in water efficiency practices is for USAG-G to meet EO 13514 and reduce water consumption 2 percent annually through 2020. Table 4 summarizes population and water demand projections within the study region.

USAG-G population censuses for 2009 and January 2010 provided the population estimates. Forecast populations reflect maximum stationing estimates from installation personnel and the Army transformation office. The effective population on-post, at any given time, is unknown due to deployments. (The current spreadsheet model does not factor in deployments.) As deployment schedules become known, this information may better inform the model projections. Family housing water use is the sum of FY2009 meter records (317,629 m³, 86,908,705 gal) for the 1484 off-post leased housing units and estimated (85,491 m³, 22,584,333 gal) for the 260 on-post family housing units. Average use per unit was used to forecast future family housing use. Ranges typically have toilet facilities and a small kitchenette providing snacks. Water use for the ranges within the study region was estimated at 1000 m³/yr (264,172 gal). Irrigation of the sports fields was estimated at 10,000 m³/yr (2.64 million gal). The current spreadsheet model does not factor in water use changes for the ranges or irrigation practices. Future changes in training intensities or irrigation efficiencies should inform the model projections.

Estimated from reimbursable facility billing records are school, medical, and commissary water use. It is important to keep in mind these are only estimates. Meters are not currently in place. Future water use for the schools is based on population projections. Future water use for the medical facility, recently renovated in 2009, and commissary are not expected to change. All other base operations are determined by subtracting billing estimates from the gate meter. Future water use for these operations reflect a community growth factor; as stationing increases, water demands within industrial, maintenance, lodging, administration, and commercial will grow proportionally. No high water users were identified. Wash racks on-post practice recycling. All new construction meets Leadership in Energy and Environmental Design (LEED) Silver ratings. A 1 percent system loss was used for USAG-G water distribution system. Projected water de-

mand also reflects compliance with EO 13514. A 2 percent reduction in water consumption was calculated for total water demand—including privatized family housing units.

Water Demand Model results indicate a current regional demand of nearly 1.5 million m³/yr (396.3 million gal/yr). If consumption rates are maintained, municipal populations are maintained, and USAG-G transformation are completed as planned, annual demand will grow approximately 110 million gal, reaching a high of 1.7 million m³ (450 million gal/yr). This is still significantly below the 3.5 million m³ (925 million gal) allotment.

Demand factors

Deployments are a large unknown for the base and can cause dramatic fluctuations in water demand. For part of FY2009, nearly 50 percent of Soldiers were deployed. The current model assumes all Soldiers remain on-post (e.g., no deployments) to reflect maximum water needs. Moreover, it is important to note that un-used water systems require flushing. To maintain the infrastructure, a certain amount of water will need to be moved through the pipes whether or not Soldiers are on-post. Deployments may also impact utility budgets. The USAG-G's water contract includes a minimum quantity of 500,000 m³/yr (132.1 million gal/yr). For 2009, the post did not meet the minimum and ended up paying for water it did not use.

When all EBG construction is completed, seven motor pools with 28 company operation buildings, battalion and brigade administration areas, 12 barracks with 154 "1+1" spaces, build-to-lease housing, a child development center, a youth activity center, an elementary and middle school, physical fitness centers, a community service center, a traumatic brain injury clinic, and a centralized post exchange and commissary complex will have been erected. All of these facilities were designed to the latest specifications required by German and US law. Water efficiency amenities include dual flush toilets, WaterSense® laundry and kitchen appliances, and recycling motor pool washracks.

Despite the unlikelihood of significant increases in regional demand, Scenario 3 investigates the impacts of higher demands. Keep in mind that changes in local agricultural practices, the addition of a water bottling plant, or other high water use industries in the region may increase water demands.

Future water scenarios

The following scenarios illustrate how different situations may affect overall water resources to USAG-G and its surrounding region.

Scenario 1. Baseline conditions

Figure 13 graphs the spreadsheet results. The region currently withdraws 43 percent of its available supplies. This is projected to only slightly increase to 49 percent by 2040. USAG-G is the primary water consumer within the region. Fifty-five percent of the total abstraction supports USAG-G operations, Soldiers, and their families.

Scenario 2. Climate change

Scenario 2 assumes a 20 percent decrease in water availability due to climate change (Figure 14). Inferred from studies by the International Panel on Climate Change (IPCC 2010) and the Umwelt Bundes Amt (2007), Bavaria's expected maximum and minimum temperature increases are 2.5 and 1.8 °C (36.5 and 35.24 °F), respectively, by 2100.

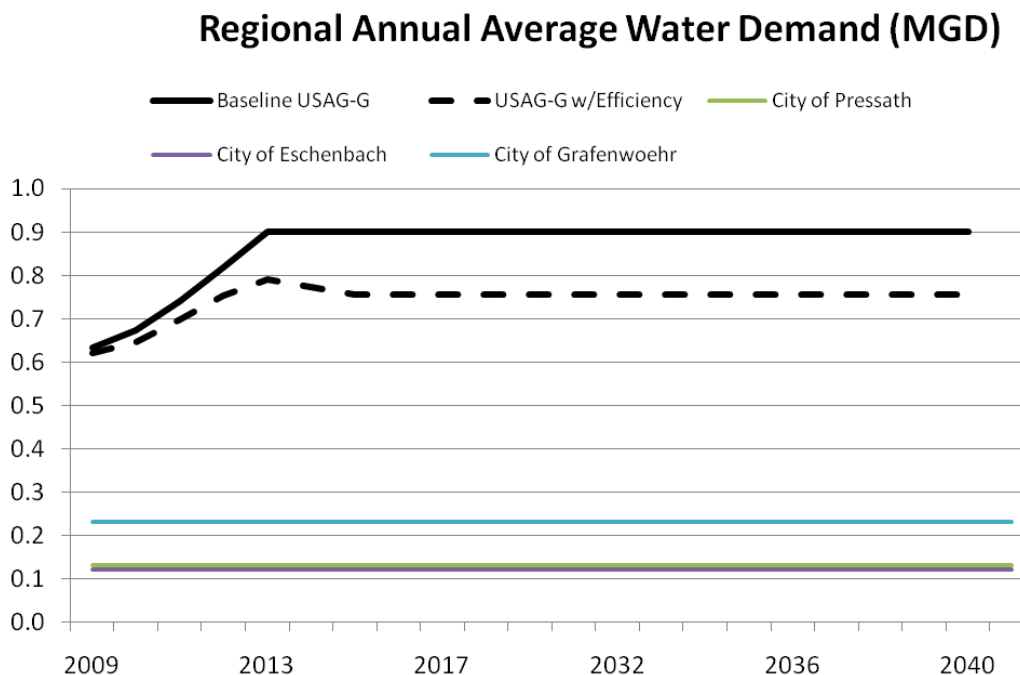


Figure 13. Baseline scenario results.

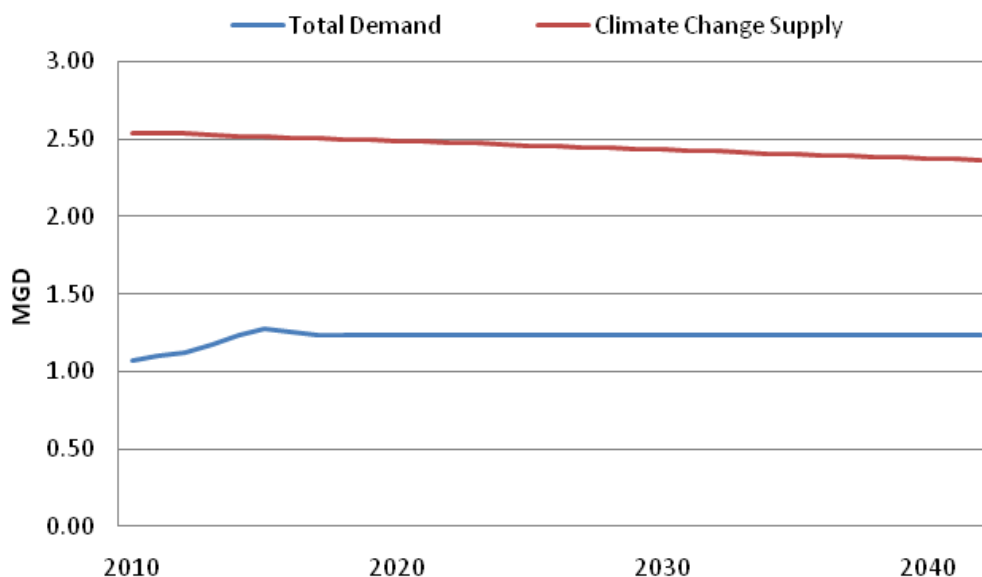


Figure 14. Climate change scenario results.

The parameter of precipitation is expected to show distinct, but opposite, trends for the summer and winter season with a net result of minor changes in annual precipitation. Over the same time period, expectations are for an increase of 20 to 30 percent in average precipitation for the winter months and a decrease of 20 percent during summer months. Because of the importance of summertime precipitation for vegetation, this scenario assumes water availability drops 20 percent. In actuality, winter rainfalls could be stored for summer supplies.

Current water supply exceeds demand by nearly 2 million m^3/yr (530 million gal/yr). By 2100, this is reduced to just over 1 million m^3 (265 million gal) in annual surpluses given the scenario assumptions. Without significant changes in regional demand, water supplies are likely to remain unstressed regardless of climate change. For the study region, this means a continued abundant supply of water resources.

Scenario 3. High water use industry

Scenario 3 investigates the impacts of higher demands. Keep in mind that these demand could come from stationing changes, changes in local agricultural practices, or industries locating within the region. The likelihood of any of these events is not currently foreseen; but the region should consider the situation.

The scenario considers additional industry within the region. Given the abundant water supplies and its location relative to the industrial centers

of Frankfurt and Munich, the addition of an industry with relatively large water demand is modeled. Average industrial water use ranges from 3785 to 908,500 m³/yr (1 million to over 240 million gal/yr) (Vickers 2001). The most common average demands are near 7,570, 75,700, 189,250 m³/yr (2 million, 20 million, and 50 million gal/yr). Figure 15 shows that an industry requiring 190,000 m³/yr (50 million gal/yr) that begins drawing from the region's supplies in 2016.

As a result, the region will be using 54 percent of its available water in 2040. This is in contrast to the baseline scenario where the region is forecast to use 52 percent of its available supply by 2040. If the scenario is coupled with climate change, 58 percent of the available supply will be consumed. Clearly, the region can support additional industry regardless of possible climate change impacts. Current water supply within the region exceeds demand by nearly 2 million m³/yr (530 million gal/yr).

Scenario 4. Cost of water

Scenario 4 considers the monetary cost of water supply. Table 5 summarizes average costs assuming an average and consistent cost of €0.60/m³. Under the baseline scenario where USAG-G does not meet the efficiency standards set forth in EO 13514, costs can be expected to rise over €250,000 by 2040 (discounting inflation). Simply by meeting the EO, USAG-G can cut that cost increase in half.

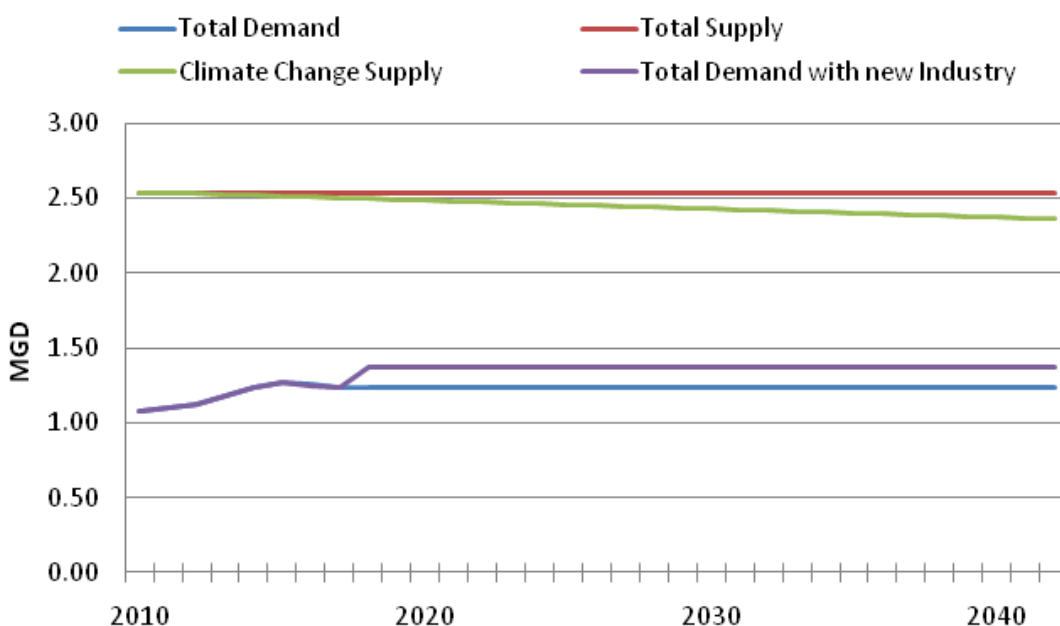


Figure 15. Additional industry scenario results.

Table 5. Cost of water scenario results.

	Baseline	2009	2010	2020	2030	2040
Baseline total annual demand (m ³)	822,283	876,499	929,003	1,242,798	1,242,798	1,242,798
Total annual demand w/efficiency		858,970	891,843	1,043,950	1,043,950	1,043,950
Cost per m ³	€0.60	€0.60	€0.60	€0.60	€0.60	€0.60
Total cost of baseline demand	€493,370	€525,900	€557,402	€745,679	€745,679	€745,679
Total cost with efficiency		€515,382	€535,106	€626,370	€626,370	€626,370
Savings from efficiency		€10,518	€22,296	€119,309	€119,309	€119,309
Water costs for family housing	€260,241	€292,771	€300,904	€325,302	€325,302	€325,302
3.8% annual increase in cost		€534,966	€555,440	€650,172	€650,172	€650,172
6.0% annual increase in cost		€546,305	€567,212	€663,952	€663,952	€663,952

USAG-G does not meter water use on-post—making it challenging to target facilities for water cost reductions. However, much of the family housing is privatized and thus metered. Billing records for family housing units indicate dramatic fluctuations in annual water use. It appears that use is highly dependent on the behavior and habits of the residents. Moreover, since the residents never pay the water bill, they have little encouragement to pursue water conservation. Table 5 shows that family housing accounts for over half of USAG-G's total water bill.

Despite the fact that the average cost per m³ incurred by USAG-G has not changed over the past 3 years, the average cost of water in Germany is increasing approximately 3.8 percent annually (OECD 2000). Some European countries are experiencing as high as 6 percent annual increase. If USAG-G were to begin experiencing similar rate increases, it would result in an additional annual cost of €23,000 to €38,000 by 2040 (again, discounting inflation).

Conclusions

Even under the worst case scenario (increased demand and decreasing supplies), USAG-G is well situated to address additional stresses on water resources. The region currently abstracts just over half of its renewable supplies and is likely to maintain a similar rate over the next 30 years. This can primarily be attributed to the regulatory structure. Germany is among the leading countries in preventive environmental protection—evident in its national awareness to conserve and protect the beauty of the German landscape and its natural resources. The German environmental administration boasts an effective and quite strict regulatory framework ensuring a comprehensive protection of water resources. Coupled with declining populations, water availability has a positive outlook within Germany.

Particular to the study region, climate change is unlikely to create future scarcities, and neither increased efficiency nor increased human demand scenarios yield dramatic changes to the overall water availability. Nonetheless, there are opportunities for improvement that involve measures as simple as installing a meter. By metering individual buildings, Directorate of Public Works (DPW) staff will be able to understand how and where water is being used, and take appropriate measures to reduce water consumption. Privatized family housing units are currently the only individually metered facilities within USAG-G. These records reflect dramatic fluctuations in water demand and suggest opportunities in education and outreach programs.

Finally, water is a mission critical resource and because USAG-G purchases majority of its water from municipal suppliers, it has limited control over availability and costs. Historically, partnerships between USAG-G and local water suppliers have been strong. It is important to ensure a continual and cooperative partnership among authorities.

Recommendations

This work recommends that USAG-G:

- *Short-Term*
 - Meet EO 13514 efficiency requirements.
 - Update Emergency Water Plan to reflect the needs of the end-state of recent Army transformations.
- *Mid-Term*
 - Conduct visioning exercises concerning water resources and incorporate scenario analyses in master plans.
 - Implement monitoring measures such as meters at individual facilities.
- *Long-Term*
 - Continue to pursue water conservation and efficiency measures.

Italy Overview

Geography, Topography, and Land Use

Italy's geography stretches from the Alps in the north, bordered by France, Austria, Switzerland, and Slovenia to its peninsular southern extreme in the central Mediterranean Sea, northeast of Tunisia. This includes a number of the islands; the largest are Sardinia and Sicily. Italy has an area of about 300,000 km² (116,200 sq mi), slightly larger than the state of Arizo-

na. Terrain is mostly rugged and mountainous with some plains and coastal lowlands. The Alps determine the northern boundary and the Apennine Mountains form the backbone of the peninsula. Italy maintains the active volcanoes Etna, Vulcan, Stromboli, and Vesuvius.

Land use in Italy consists of 31 percent arable land and 8 percent permanent crops. Permanent pastures comprise 25 percent and forests and woodlands make up 15 percent. The remainder of land uses total 21 percent. Urbanized areas grew by 15 percent from 1991 to 2001 (comprising 6.4 percent of land), while population grew by 0.4 percent.

Climate

Italy's climate is primarily Mediterranean with Alpine influences in the far north and hot and dry in the south. Altitude, distance from the sea, and aspect account for local weather variations. Winters are cold in the mountains while the coasts are warmed by the sea. Winters from Northern Europe spread south into Italy bringing snow to most mountains. Alpine ski resorts in the north average -8°C (17.6°F) in January while the southern coasts average 8°C (46.4°F). In summer, hot weather from Africa moves north through the entire country. Large areas of Italy average 24°C (75.2°F) all summer. Precipitation declined by 10 percent from 1994 to 2004, reducing surface flow by 20 percent for most principal basins. Precipitation varies regionally from 265.2 to 761 mm (10.42 to 29.91 in.) per year in Termoli in Piacenza–San Damiano.

Water Quality

Water quality differs regionally in Italy, and is affected by pressures both natural and anthropogenic. Point source pollution, from civil and industrial sources, is matched in prevalence with diffuse pollution from agriculture, livestock, and urban areas (Farrace, Giuseppina, and Pineschi 2007).

River quality is degraded, particularly when medium or small streams drain areas with high urban and industrial concentration. Examples include the Lambro River draining Milan, the lagoon of Venice, and the reaches of the Po, Arno, and Tevere downstream of Torino, Florence, and Rome. Industrial districts with heavy impact include the tanning and textile industry in the North and the food industry in the South (Massarutto).

While The European Union reports an overall drop in nitrate concentrations across the continent, in Northern Italy nitrate levels remain high. Ni-

trate concentrations above 50 mg/L (50 parts/million) (the public supply limit in the EU) are common in the coastal plains, along the basin of the Tevere, and in the Po basin. Heavy concentrations of pesticides are also found in areas of heavy cultivation. Bacteric and heavy metals reach water from landfills, abandoned industrial sites, direct discharge (now forbidden), and the use of polluted fertilizers such as compost and sewage sludge (Massarutto).

Demographics

Italy's population is expected to continue to grow until 2014 to about 59.2 million, after which it will begin a slow gradual decline as the numerically strong cohort group ages to a forecast population of about 55.8 million (Marsili 2006). Italy is currently taking a tougher stance on its immigration policy because of recent influxes of illegal immigration. Between 2008 and 2009, the number of illegal immigrants into Italy increased by 75 percent; as a result, Italy has begun to take harsher measures against illegal immigration by increasing fines and allowing a citizens' patrol to help identify illegal immigrants (BBC 2009).

Water resources

Although Italy ranks 208th globally for economic growth, it retains 11th place globally for Gross Domestic Product (GDP) per annum, and is ranked 14th and 13th for energy production and consumption respectively. Italy has approximately 27,500 km² (10,619 sq mi) of irrigated land. It had an estimated 175 km³ (38.5 trillion gal) of surface water sources, however through reconsiderations of natural loss and impracticality of using some of the "in theory" available resources, that estimate was reduced to 110 km³ (24.2 trillion gal) in 2007 by the *Agenzia per la Protezione dell'Ambiente e per i servizi Tecnici*, Italy's Environmental Agency (APAT). According to numbers recorded in 1998, Italy's withdrawals are approximately 42 km³ (9.2 trillion gal) for domestic, industrial, and agricultural use. Current water availability is estimated at 51.8 km³ (11.4 trillion gal); however Italy's withdrawals are expected to increase to 53 km³ (11.7 trillion gal) by 2015 due to increased tourism, and agricultural and industrial needs. Italy has one of the highest withdrawal rates per capita in Europe with 723 m³ (191,017 gal) per person per year.

Data collection for Italy is often incomplete so exact extraction and water service data are unavailable, thus withdrawal and supply forecasts are expected to have error (ZARAGOZA 2007). Despite the error, the estimated

per capita withdrawal and increase in demand may be partially due to the increase in tourism. According to country reports by the EEA, the Mediterranean as a whole has seen an increase in tourism of approximately 90 percent in the last few decades. The EEA studies show tourists habitually use more water than non-tourists.

Expected impacts of climate change

The effects of climate change on Italy and southern Europe have the potential to develop into a desert-like climate. The arid southern regions of Italy are forecast to become even drier as the expected number of rain days decreases along with an eventual reduction of overall precipitation. Rain events, despite their decreasing frequency, will become more extreme, potentially increasing the risks of flash floods in mountainous regions. As the global temperature continues to warm, the Alpine snow will continue to recede while ocean water will continue to rise on its coastlines. Subsidence of land due to over-pumping within coastal aquifers, such as the Po Basin, will contribute to the salt water intrusion, and increase the stress on the water resources.

Water policy

Although Italy is fully aware of its potential water shortages, it has been slow to follow EU guidelines in adopting the WFD directive. Italy's recent restructuring of its constitution and decentralization of authority has allowed more autonomy at the provincial levels while allowing more stakeholders to be involved in water management at all levels. This will create more bureaucracy. The complexity of its administrative system is demonstrated in its current water laws. The current legal water framework is guided by three main laws or decrees. These decrees are:

- Legislative Decree 183, L. n. 183/1989, passed in 1989 (183/1989)
- The Galli Act, L. n. 36/1994, passed in 1994 (36/1994)
- Law D.lgs. n. 152/1999 (152/1999).

Law 183/1989 deals with the protection of the watershed and the water resources, safeguarding of water heritage, and the uses and management of water. Law 183/1999 initially defined the River Basin Authorities (RBAs) throughout Italy, however, its intent was to actually address soil protection. The law included water management as a holistic approach to address point source pollution. As part of the law, the RBAs were tasked with determining investment priorities in water supply, sewerage, and wastewater treatment infrastructure for their area.

The Galli Act (Law 36/1994) deals with water services, uses and management and contains general principles. Law 36/1994 introduced the concept of water as a public resource to be managed and established Optimal Territorial Areas (ATOs), which are locally defined areas under local administrative control that provide integrated environmental management. Their creation may have been intended to deal with the conflict of multiple RBAs within one province, but in fact, both the ATOs and RBAs often conflict and overlap in their management responsibilities. As a result of RBAs initial presence, actual administrative integration of ATOs has been heterogeneous and disjointed.

Law 152/1999 aims at the integration of environmental, health, economic, and productive policies toward a global policy of water resources management. Law 152/1999 sought to reverse the decentralization of water management by integrating policies under one regionalized Water Protection Plan. This law anticipated many of the requirements listed by the EU's WFD; however it does not require the RBA boundaries to comply with EU's definition nor does it clarify administrative authorities for the RBAs to report to the WFD. With its current water policies and existing administrative infrastructure, Italian regions have been unwilling to change to comply with the EU's WFD. As a result, Italy has been unable to adopt the WFD into its national policy (Goria 2002).

As a result of the administrative backlash against adopting the policies of the WFD, Italy has been found guilty of breaching its obligations under the WFD for not properly transposing the WFD into national legislation in 2004. In February 2008, Italy was found guilty of also breaching the WFD by not providing the environmental analysis of pressures and impact under Article 5. As of July 2008, fines had not yet been set for the infraction. In comparison, France was fined €31,000/day or €57 million every 6 months (including a lump sum payment of €20 million to the EU) for similar infringements. Italy's track record in following the EU's WFD is among the worst of the 27 member countries; therefore, its penalty payments will depend on whether Italy and its regions begin to fulfill their obligations set under WFD.

Despite its poor water policy history with the EU, Italy is making progress in water management that would probably not have been achieved if the WFD had not come into effect. Legislative actions for water treatment and protection started locally back in 1994 under the Galli Act, but it was not until 1999 and 2003 that the Italian Ministry decreed technical require-

ments to treat wastewater and to provide operational tools to manage water resources. The EU's biggest concern for Italy is the lack of data according to the river basin borders described nationally and internationally by the EU. Water protection plans have been developed by individual regions within Italy, but their methods vary from one to another; thus river basin typologies and classifications differ between regions and also differ from EU standards. Most Italian river basin authorities have not completed an economic analysis as directed by the EU and thus these data have not been compiled or sent onward to the EU. On top of the incomplete data, composed geographic information system (GIS) maps are different from one region to the next. Overall Italy has made no national standard for analyzing its water resources or characterizing them, let alone enforcing standards set by the EU. Italy is sending data to the EU, but the quality of that data is not up to usable standards. In the end, the content of Italy's data collection will have to be studied separately from that of the EU and will be dependent on each individual region (Gruppo 183 2006).

US Army Garrison Vicenza

Camp Ederle is located in the Veneto region in the upper northeastern part of Italy—one of the wealthiest and most industrialized regions of Italy. It is also one of the most visited receiving about 13.5 million tourists a year (Regionale del Veneto 2007). The combination of agriculture, industrial, and tourist economy has put an intense strain on the water resources available. Camp Ederle is located in the Vicenza province which is one of seven provinces located within the region.

Currently, the Veneto region is part of three separate river basin authorities defined by the Environmental Agency of the Veneto Regional Government (IPAT). In contrast, the EU has defined Veneto Region primarily under the Eastern Alps River Basin District as shown in Figure 1. The Italian defined basin authority for the area surrounding USAG Vicenza is comprised of many small river basins defined by IPAT. These small basins include the Isonzo, Tagliamento, Livenza, Piave, and Brenta-Bacchiglione Rivers Basins (Figure 16). The Brenta-Bacchiglione River Basin (BBRB) encompasses USAG Vicenza, and includes parts of the Provinces of Trento, Verona, Vicenza, Belluno, Treviso, Venice, and Padua. USAG Vicenza has multiple sites and is located adjacent and within the city of Vicenza which is the capital of Vicenza Province.

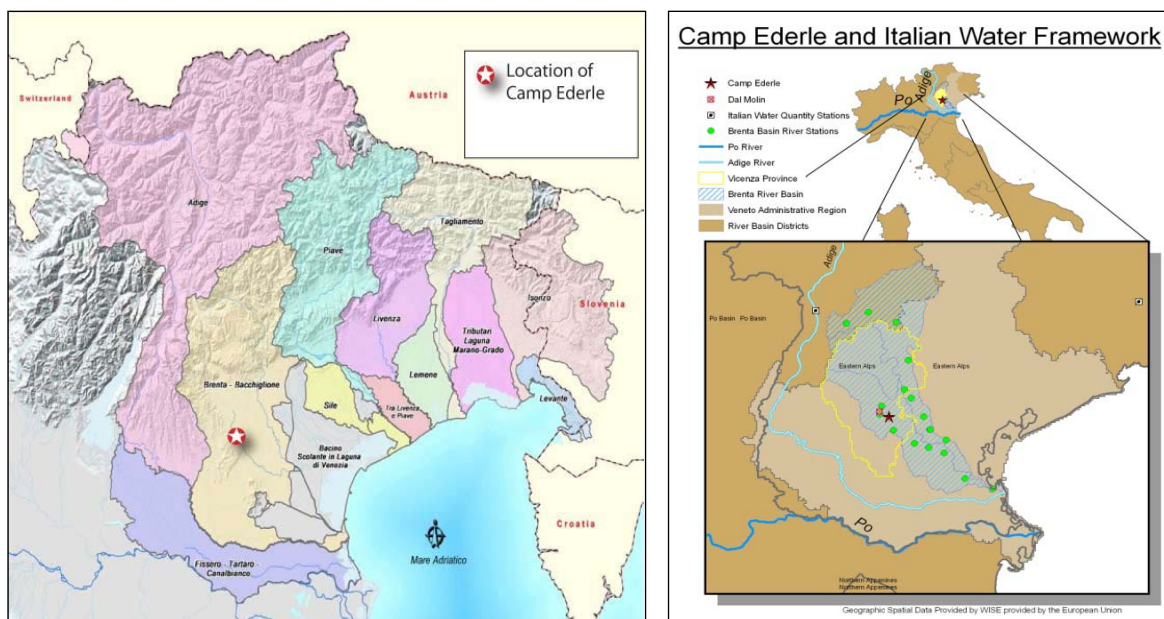


Figure 16. USAG Vicenza Region (source Regional Del Veneto. Data: EEA WISE 2007).

Region of analysis

Water availability trends in the Veneto Region show depletion in ground-water storage. Measurements from recharge areas show a lowering of the water table by seven to eight meters, disappearance of natural springs, and a three to four meter depression in the artesian aquifers since the 1960s. Studies done in the region indicate inflows to the water system are less than the flows out, resulting in a progressive reduction in groundwater reserves (Regionale Del Veneto SSE, 2008). Rains and mountain runoff in the last two years have been above average and local aquifer water tables have risen slightly as a result, but not to the same levels reported in the 1960s (Report on Veneto Regions Water Sources, 2010).

Area private water suppliers have changed from AIM* Vicenza Spa to Water Vicenza. Water Vicenza serves 31 municipalities, 285,000 people, including the City of Vicenza. Although, the Bacchiglione River runs through the city of Vicenza, parts of the river in Vicenza Province have rated “poor” water quality due to intense local fertilizer use and wastewater from industrial plants. As a result most of the potable groundwater in the province is extracted from the main recharge area of the regional aquifer, “Alto Vicentino,” located north of Vicenza City (URS Greiner Woodward Clyde International Inc. 2003). The “Alto Vicentino” aquifer is an alluvial fan 10

* AIM is a national Municipal Industrial Company which is privately owned but provides services such as gas, water, energy, and transportation to several Italian regions.

to 20 miles north of Vicenza City near the Comme Setti Plateau within the Vicenza province. Figures 17 and 18 show the relative position of the recharge zone in the larger aquifer and its construct as it relates to Vicenza City. The “Alto Vicentino” recharge zone has a high enough recharge rate that it is entirely renews the aquifer beneath it every 8 to 9 years (Otto, 2007).

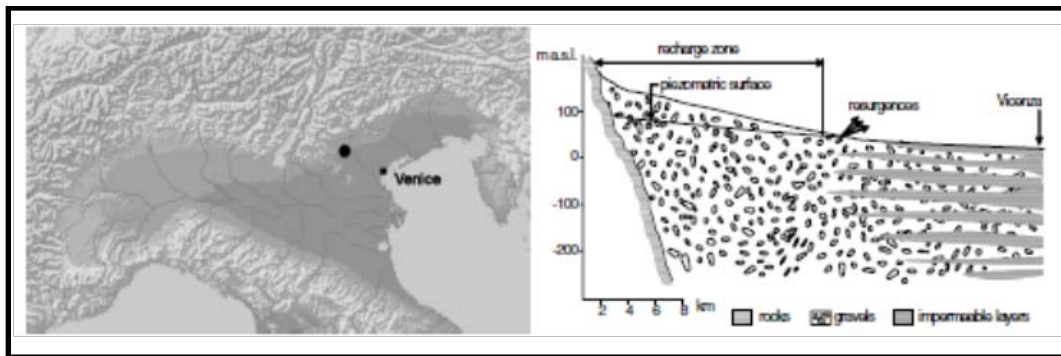


Figure 17. Location of the Alto Vicentino aquifer in north-east Italy and its longitudinal layout.

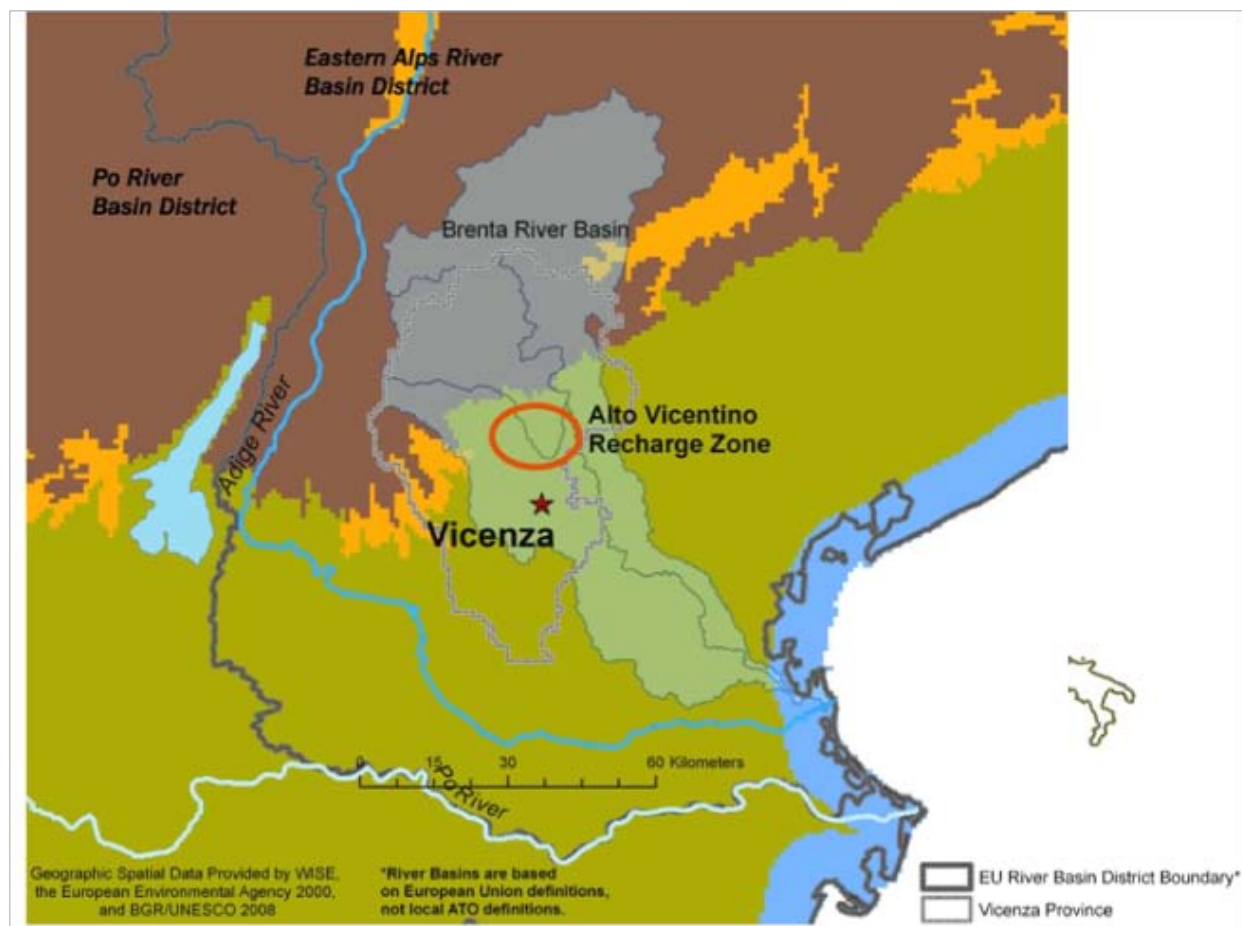


Figure 18. Region of analysis for USAG Vicenza case study.

Since this recharge zone and its supply are the primary water supply for the inhabitants of the surround municipalities, this water budget analysis was limited to this zone and the existing wells within USAG-V. Industrial plants and water irrigation uses have been factored into the zone's water balance from previous studies by AIM. Current estimates of the recharge zones water balance were based on studies done by AIM on the aquifer back in 1982 and 2001, but have been adjusted to match the current demand and recharge.

Regional water management factors

Water policy

The Veneto Region has adopted the newest legislation, 152/2006, to comply with EU regulations; however re-designation of its basin boundaries has yet to be approved at the national level. At the same time Veneto Region has ATOs to which it delegated the organization, custody, and control of water management while maintaining RBAs as defined by the 183/1989 decree. Though RBAs are tasked to develop water management priorities at the regional level, the autonomy of provinces does not guarantee that priorities match at the local level. Veneto's current framework places costs of operation and management on the local administrations while requiring its provincial administrations to also abide by the 152/2005 water management guidelines (Regionale Del Veneto, Public Relations Office 2009). Once Italy officially adopts all aspects of the 152/2006 decree in order to abide by the WFD, actual implementation at the provincial level will depend on individual provinces.

Despite its legal infractions against the EU's WFD, Italy's water management is becoming more of a priority, especially in the Veneto region where Camp Ederle, Vicenza, and Venice are located. Venice, a huge tourist attraction, is slowly sinking into the ocean. Due to intense irrigation in the Veneto region from groundwater withdrawal, the aquifer beneath Venice is subsiding, causing Venice to subside. At the same time saltwater intrusion into the region is causing damage to crops and natural vegetation. To hasten the problems affecting Venice and the region, climate change forecasts project that sea levels will rise by up to a meter during the next one hundred years. In addition to the threat of further subsidence, climate forecasts project that the number of annual rainfall days in Italy will decrease in the region to further the water stress (Meneguzzo 2004).

Regional interpolation

Demand numbers for the municipalities from their surrounding water suppliers, as was demand information from Water Vicenza or local officials. However, this area's demand proportions were interpolated from estimates of the entire Veneto region and then adjusted the demand to fit the relative Water Vicenza service population and allocated industrial and agriculture demand based on Veneto region percentages consumption relative to municipal consumption (Zaragoza, 2007). 1982 estimates by AIM gauged water demand to be 104 MGD (Sottani et al. 1982 and Pesavento 2001). Through factoring population growth, increased standard of living, and industry, it was estimated that the area's 2009 baseline demand would have grown to approximately 156 MGD (Table 6), which would correlate to the relative overdraw in demand causing the lowering of the regional water tables mentioned above.

Tourism

Regional tourism has grown five percent since 2001 despite a decline from 2002 to 2004. Considering the economic downturn in 2008, tourism in the Veneto region was relatively stable, dropping 0.2 percent from 2007. Domestic tourists are second to German tourists in number of visitors to the region. Increases in tourism may further stress the supply of freshwater resources, since tourists are known generally to use more water on average than locals (Regionale del Veneto, SSE 2008).

Garrison water conditions

Camp Ederle's potable water system consists of two groundwater production wells, #2 and #5 that are owned by the United States and two in-ground storage components with a combined capacity of 2,736 cubic meters. This system was originally installed in the mid to late 1950s and supplies the domestic, industrial, and fire protection water requirement for the garrison with the exception of 8 buildings which are supplied by the City of Vicenza municipal water system. Due to peat deposits within the aquifer beneath USAG-V, water from well #2 has had detectable levels of ammonia. Adjacent industrial sites also contribute various types of Chlorinated Hydrocarbons (CHC's) that has been found in water tests. To combat contamination, USAG-V operates two primary water treatment plants: one at Caserma Ederle and one at the Villaggio Family Housing Area. USAF-V also provides secondary disinfection for the ASA-7 and Longare water systems which are connected to municipal water systems.

Table 6. The “Alto Vicentino” recharge zone water budget (2009 Recharge Zone Water Budget).

Input	MGY	MGD
Active rainfall	57,325	157.1
Leakage from rivers and streams	89,290	244.6
Leakage from irrigation systems	20,341	55.7
Underground inflow	1,189	3.3
Total (A)	168,146	460.7
Output		
Resurgences	122,048	334.4
Withdrawal*	56,940	156.0
Underground outflow	1,057	2.9
Total(B)	180,044	493.3
Balance(A-B)	-11,899	-32.6
Aquifer Volume	998,571	2,735.8
Replenishment time (years)	8.43	
Source: Otto, 2007 modified from Sottani et al. 1982 and Pesavento 2001		
*2009 estimate		

As recently as 2008, Camp Ederle experienced some water quality issues in both March and August and was forced to provide bottled water for servicemen and restaurants on base. The recent contamination may have been caused from installation of new pumps (Harris, 2008). Despite the initial contamination, the newly installed pumps and distributions systems have likely lowered the loss rate for USAG Vicenza to below the rate of local municipal systems. Current estimated loss rate is assumed at approximately 8 percent, however, this has yet to be verified by actual testing (Sartori 2009).

With the expansion of Camp Ederle into Dal Molin, the water management system may require an update of the hydraulic capacity and potable water systems, while possibly installing an additional drinking water early warning monitoring system (Bosetti, 2008). Due to local restrictions on drilling well with Dal Molin’s perimeter, facilities will be supplied by the local municipal water supplier, Water Vicenza (Sartori, 2009).

Water supply model

Alto Aquifer recharge zone

Independent research on the “Alto Vicentino” aquifer recharge zone and its properties have given similar estimates on its capacity and replenishment rates (Otto 2007, Zanin 1992). Their water balance analysis was used

to form the 2009 baseline for these supply projections from which to base the effects of climate change on future capacity and recharge (See Table 6). Using the factors present in their water budget, applicable increases or decreases in inputs or outputs were applied depending on the Intergovernmental Panel on Climate Change (IPCC) 2007 climate change report on how these factors may change out to 2040. The extent of change is explained the Climate Change section below.

Existing wells

Both wells draw from the same aquifer that is recharged from the “Alto Vicentino” recharge zone. The transmissivity of the recharge zone creates a huge potentiometric head that pushes southeast outward to the coast of Venice. The high pressure groundwater essentially makes the existing wells at USAG-V artesian springs supplied by the 2.9 MGD recharge outflow per day.

Well #5, which supplies Caserma Ederle, has an estimated 100 percent efficiency pumpage rate of 0.73 MGD, and Well #2, which supplies Villagio Family Housing, has a daily capacity of 1.52 MGD. Both of which are more than enough to support the current demand at the garrison (URS Greiner Woodward Clyde International Inc. 2003). This supply model assumes the recharge to the wells comes from precipitation and underground inflow from the potentiometric head from the “Alto Vicentino” outflow, estimated at 2.9 MGD. Precipitation recharge to the aquifer is estimated at 1250 mm rain per year over the 439 acre area of the existing garrison. With a 54 percent loss in evapotranspiration a 0.56 MGD recharge rate was calculated for the surrounding aquifer (Zanin, 1992).

Climate change

IPCC forecasts for the northeast region of Italy include an average temperature increases of up to 6 degrees in the summer months by 2070. With the increase in temperature, summer precipitation is expected to decrease by 30 to 45 percent and up to 70 percent in some areas by 2070. Yearly maximum temperatures are expected to rise along with the intensity of rain events despite reduction of rain events in overall number of days. As such, the Veneto Region should expect a pronounced increase in year to year variability in climate with droughts to start earlier in year and last longer. Conversely, when it does rain, it will be more intense and will increase the likelihood of dangerous flash floods. Warmer winter temperatures will increase winter river flows due to glacial melting, but after glaciers recede fully, summer flows may decrease up to 80 percent by the end

of the century. Models ran by researchers at IPCC indicate that overall runoff will likely decrease from 0 to 23 percent by 2020 and by 20 to 30 percent by 2050. With increase temperatures and water stress, energy consumption is projected to grow twice as fast as the increase in total normal consumption brought on by the population desires for higher comfort levels and larger dwellings. Changes in the amount of agricultural area in northeast Italy are unlikely to change substantially by 2030 despite increases in productivity. In fact, if Veneto becomes more water stressed an increase in irrigation demand is likely (IPCC 2007).

Water demand model

Since some of USAG-V stationed population lives off the local municipal services, estimates for on base population and consumption per capita were based off a combination of factors in order to match the overall metered consumption numbers provided by USAG-V staff. Adjustments to the demand model included deployments, water fixture types, growth estimate, garrison housing, and population estimates. Overall consumption for both Caserma Ederle and Villagio for 2009 brought different estimates. Sewage water utility data gave 0.3 MGD whereas water utility consumer's worksheets estimated 0.15MGD. The 2008 Potable Water System Master Plan(PWSMP) estimated overall normal demand to be more around 0.44 MGD. This overall estimate resulted after taking into account housing, population, deployment, and fixture types. This estimate of water consumption was slightly higher than the 2008 PWSMP. For the 2009 baseline, USAG-V demand is estimated to be around 0.52 MGD. The below factors describe how this number was calculated.

Deployments

Deployments heavily factor into overall water consumption through the USAG-V sites. Since many dependents travel elsewhere while servicemen are deployed, a large percentage potential base population is often absent. These absences were factored in this demand model to better reflect potential future consumption while matching the baseline data of this model to actual meter readings.

Efficient fixtures

The macros in this model are historical consumptions rates off American Water Works Association (AWWA) standards. However, fixtures at USAG Vicenza were a combination of standard and dual flush varieties, with some

high efficiency shower heads. Due to this integration of efficient fixtures in the barracks, administrative buildings, and some family housing, a 10 percent lower consumption rate for housing and administrative structures was factored into this demand model to reflect actual usage on garrison.

Growth

Construction projects for Camp Ederle will rebuild the majority of the base within the next 10 years. This massive construction plan is due to the projection that four battalions currently stationed in Bamberg and Schweinfurt will be moved to USAG Vicenza by FY2011. The estimates assume that 2,000 military personnel will be stationed at a new site near Dal Molin Air Field within the next 5 years, so the number of military personnel at Ederle may initially increase but then decrease as troops migrate to the new site. Also, personnel from AFRICOM are likely to be stationed at Camp Ederle, but specific numbers were not available. A separate study is currently underway to review the water system at Camp Ederle and to determine how all users will be supplied as new facilities come on line.

There are plans to extend the military footprint in Vicenza to include all elements of the 173rd Airborne Brigade Combat Team. Vicenza is eventually slated to be home to all six battalions of the 173rd Airborne Brigade. Currently, only two infantry battalions and portions of the brigade's two support battalions are in Vicenza, and the move would bring the total number of stationed troops in Vicenza to 4,200. Expansion of the US military into Dal Molin (Camp Ederle-2), a decommissioned airfield roughly two miles from Camp Ederle, has sparked intense political and public debate in the northern region of Veneto. The project, approved by a joint Italian-US Military Construction Committee working under the 1954 Bilateral Infrastructure Agreement, calls for 25 new buildings with lodging for 1,200 soldiers and multi-story car parks for over 800 vehicles (Westbrook 2009). Construction was proceeding in July 2009 with pile driving; above ground work is expected to begin in September 2009 with the entire project complete by summer 2012 (Ciccotti 2009).

On garrison housing estimates

USAG Vicenza has a shortage of on base housing and as a result, some of its housing is leased off-base. Current on garrison housing consist of 1219 barracks, 247 family housing, 350 government leased housing. New construction will include 1208 barracks on Dal Molin, with 241 built to lease planned by 2012, and an additional 300 regular government leased hous-

ing (Smith, 2010). Assuming the listed and future housing types will be supplied by the existing wells and municipal connections at Dal Molin, current and future consumption of the housing types, number of servicemen and dependent living in those units were based. Water consumers remaining off base were estimated based on 1/3 of remaining servicemen, dependents, contractors, and retirees to reflect 8 hour work days.

Demand model results

Starting from the 0.52 MGD baseline and factoring the expected base growth, the estimated water consumption for 2040 is 0.82 MGD without water conservation measures directed by E.O. 15314. With water conservation, an initial consumption growth is expected up to 0.76 MGD by 2012, but lowering down to 0.61 MGD by 2021 with water conservation measures out to 2040. A demand scenario which would reflect a stable base population with no major deployments was also created. Under this scenario, demand for USAG-V could go up to 1.0 MGD, but with water conservation requirements, a stable demand of 0.74 MGD is forecast from 2021 to 2040 (Figure 19).

Three water price scenarios were estimated to compare annual costs. Estimates based of the 2009 rate were created using a rate based off potential unit prices per 1000 gallons, Water Vicenza integrated rate, and a potential rate for a water stressed region. The 2009 unit price is \$2.58 per 1000 gallons. Since Dal Molin must be supplied by the local municipal system, an initial hook up fee of one million dollars will be added to their fees beyond the cost for infrastructure (Jenicek, 2010). Based on this increased cost and current Water Vicenza rates, rates are expected to increase to an average of \$ 3.50* (Water Vicenza 2010). In the possibility of a regional water stress development, it is estimated that water prices would increase to approximately \$4.50. Figure 5 shows the annual costs of each of these scenarios. With expected growth and demand current 2009 utility rates will cost \$850,000 dollars per year. Possible rates increase with Dal Molin's connection would increase the annual cost up to \$1.05 million dollars. Possibly water stress would then further increase costs to \$1.35 million dollars annually (Figure 20).

* 2010 Water Vicenza rates are \$3.80 per 1000 gallon.

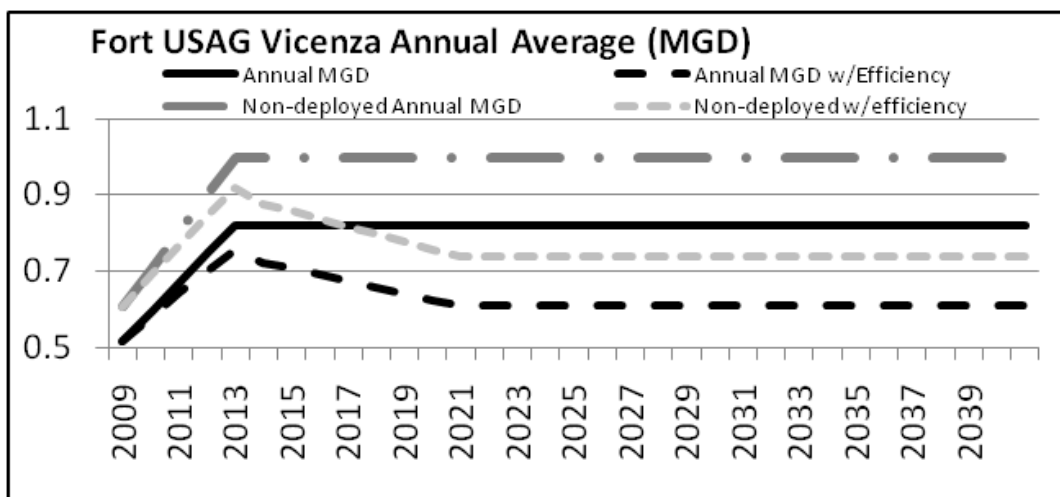


Figure 19. Forecasted demand for USAG Vicenza out to 2040.

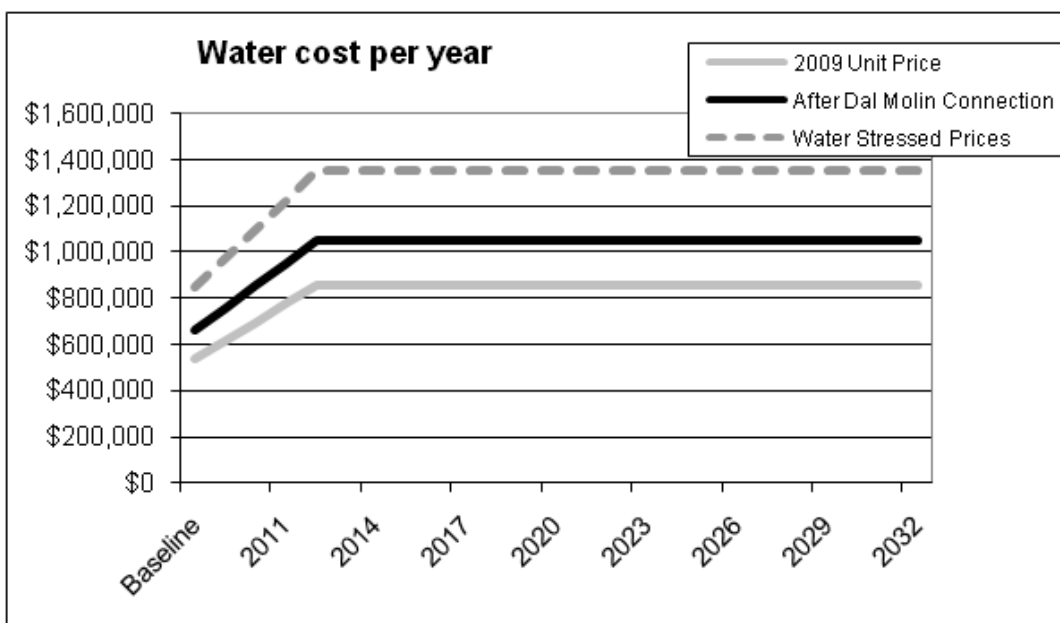


Figure 20. Annual water cost scenarios.

Future Water Scenarios

The aquifer storage estimates give is 958,571 MG for the area of study (Otto to 2007). With this as a baseline, these scenarios were fashioned to compare what relative remaining storage would be available in 2040 resulting from current policies, practices, and possible climate change (refer to Table 6). With the growth and addition of Dal Molin, the potential demand required by Dal Molin was factored into the demand required by Water Vicenza as it would take from the “Alto Vicentino” recharge zone. Since the pumps supplying water to Vicenza are also supplied from the recharge

zone, the increased demand of Dal Molin into a relative impact on the available recharge to USAG Vicenza was factored into Table 7.

Table 7 breaks down the variables and degree in change that were factored into each scenario. The percentage increases are taken from estimates derived from the IPCC 2007 climate change forecasts. Moderate Climate change scenarios(#1,#4,#5) include a decrease in precipitation, basin transfer, basin recharge, and underground flow of 20 percent and increase in demand as a result of temperature increase of 15 percent. Extreme climate change(#2) include a decrease in the same factors of 45 percent with an increase in demand of 30 percent. Scenario 3 has no climate change influence, but reflects regional and base growth due to BRAC. The data in Table 7 may be used to compare the relative overall remaining water storage remaining in the aquifer. The numbers provided are not exact, but given as a descriptor to compare the possible relative state of the aquifer in 2040.

Table 7. Scenario variable baseline influences

Scenario Variables					
1	2	3	4	5	
Vicenza Recharge Zone					Variables
2%	2%	2%	2%	2%	Percent Reduction due Water Conservancy
-20%	-45%	0%	-20%	-20%	Change in precipitation by 2040
-20%	-45%	0%	-20%	-20%	% Recharge to Basin Transfers
15%	30%	0%	15%	15%	Increased irrigation recharge
-20%	-45%	0%	-20%	-20%	Change in inflow recharge
-20%	-45%	0%	-20%	-20%	Change in Resurgence base on lower recharge
15%	30%	0%	15%	15%	Change in Demand based on Higher Temperatures
-20%	-45%	0%	-20%	-20%	Change in Underground outflow
USAG Vicenza Well					
2%	2%	2%	2%	2%	Percent Reduction due Water Conservancy
-20%	-45%	0%	-20%	-20%	Change in Natural Recharge
-20%	-45%	0%	-20%	-20%	Change in underflow recharge due to limited outflow
15%	30%	0%	15%	15%	Change in Demand based on higher temperatures

Scenario 2

Extreme climate change assumes a temperature increase of 5 degrees by 2040. The same variables listed above are affected, but this time with a decrease in precipitation, recharge, basins transfer, and underground outflow by 45 percent. Increase in demand due to temperature increase will increase by 30 percent. Increased irrigation from rising temperatures will likely increase the irrigation source recharge to the aquifer by 30 percent.

Scenario 2 result

For the possible extreme changes in climate, one can expect and ever more severe depletion of the storage of the surrounding aquifer. In this scenario, only 31 percent of the aquifer capacity would be maintained by 2040 due to the limited recharge and increased demand. The limited recharge would also lower available surplus to 1.2 MGD as demand should increase to 0.72 MGD, but still should not hinder USAG-V well supply.

Scenario 3

Despite proven ongoing effects and forecasts repeatedly reinforced by different models, there is still doubt about the prospects of climate change. A third scenario that demonstrates no change in temperature or precipitation was run.

Scenario 3 result

With no climate change, the aquifer demand still out paces supply, but the depletion is considerable less with a continued storage capacity of 640,000 MG, maintaining over 64 percent. A surplus of 2.9 MGD reflects the 0.56 MGD precipitation and continued inflow of 2.9 MGD subtracting for forecasted USAG Vicenza demand of 0.56 MGD.

Scenario 4

Scenario 4 reflects a garrison experiencing moderate climate change who has implemented a comprehensive water conservation program that goes above and beyond the E.O. 13514 requirement of 26 percent reduction. Estimates for a total water management (TWM) by the Pacific Institute estimate a community could reduce its consumption by up to 40 percent. The additional 14 percent reduction was integrated into this scenario around 2021 to follow the pace of E.O. 13514 implementation.

Scenario 4 result

As Dal Molin is also factored into the TWM some effect on recharge zone demand is shown with a slight decrease in water storage deficit compared to Scenario 1. Surplus for wells #5 and #3 showed an increase of 0.1 MGD due decrease demand down to 0.54 MGD as compared to Scenario 1, but with an overall increase in recharge zone capacity of 666 MG giving a total of 484,213.

Scenario 5

With the BRAC re-structure, it is hoped that regular deployments will not be a fixed operation requirement of USAG-V's population. As such, both demand and supply scenarios were created in which USAG-V population is fixed and stable. This scenario assumes both moderate climate change and E.O. 13514 implementation.

Scenario 5 result

With a stable population with E.O. 13514 implemented, demand is expected to increase to 0.68 MGD by 2020 and remain steady to 2040. A constant base population would increase regional demand deficit and decrease aquifer storage with moderate climate change by 4,837 MG, or 0.5 percent by 2040. Surplus to the wells would be reflectively less than scenario 1 and 4 with 2.1 MGD surplus.

Conclusions

Due to the consistent water surplus in these scenarios, water quantity is considerably less of concern than water quality; however, significant attention should be paid towards the regional recharge zone and its importance to the region. Recognition of the potential future water stress that the region may face should be anticipated despite events of excessive rain. Extreme rain events are also indicative that the abnormal variability in weather is a product of global warming and is likely to increase in severity over time. With these new standards, historical context in weather will begin to become less important as the increasing temperatures change these expectations. That being said, water stressed regions are more likely to increase their costs of water service to offset the increase demand.

Although water quantity is likely to remain secure, USAG-V should remain vigilant about monitoring it quality. Recent water systems surveys have already discussed improvement suggestions and USAG-V has responded

by updating its pumps and distribution system. As such, if or when the remaining two wells supplying Caserma Ederle and Villagio Family Housing become unusable due to water quality issues, and USAG-V becomes totally reliant on the municipal system, the garrison should anticipate increased water costs and further water conservation measures.

Recommendations

Immediate

1. Investment in conservation practices that extend beyond the boundary of the garrison should be explored. As USAG-V is intimately integrated with its surrounding community so should the conservation. Much of the intent of this study is to galvanize garrison staff to think regionally and coordinate with local officials. Although easier said than done, it is hoped that both the energy and water conservation requirements serve as a segue.
2. Require LEED 3.0 building standards in new building designs.

Short Term

3. Implement high efficiency program that retrofits standard toilet and shower head designs with high efficiency fixtures.
4. As part of new building construction, design surrounding landscape to limit storm water runoff into municipal system to help mitigate extreme rain events for downstream municipalities.

Long Term

5. As Veneto Region is forecasted to receive more variability in weather, consider green roofs designs as a means to both lower energy requirements and stormwater runoff.

4 Far East Theater Case Study

Current economic growth and urbanization rates in China and Korea exemplify the trends of higher demand and changing water use patterns that are common to the Asian region.* A common example from the Leadership Group on Water Security in Asia (April 2009) reads:

Forecasts for the next 15 to 20 years see continued mass migration from China's countryside to the cities, which is likely to exacerbate the current challenges of water pollution and supply shortage. Nationwide, the demand for water in China's urban areas is growing more than 10 percent annually, and it is expected to increase 40 percent by 2020. China's double-digit economic growth has also greatly increased water demand for industry while decreasing the quality of supply through rampant waste dumping and industrial pollution.

While home to more than half of the world's population, Asia has less fresh water —3920 m³ (~1 million gal) per person— than any continent except Antarctica. Almost two-thirds of global population growth is occurring in Asia, which is expected to grow by nearly 500 million within the next 10 years, mostly in urban areas. In November 2008, The US National Intelligence Council highlighted Asian water scarcity in its Global Trends 2025 report: "With water becoming scarcer in Asia and the Middle East, cooperation to manage changing water resources is likely to become more difficult within and between states" (Saleem 2009).

As population growth and urbanization rates in Asia rise rapidly, stress on the region's water resources is intensifying. Global warming due to climate change is expected to intensify the situation. Experts agree that reduced access to fresh water will lead to a cascading set of consequences, including impaired food production, the loss of livelihood security, large-scale migration within and across borders, and increased economic and geopolitical tensions and instabilities. Over time, these effects will have a profound impact on security throughout the region (Hsu 2009).

* This study will try to limit the discussion of Asia to the northeast region to include China, Japan, and North and South Korea. However, unless noted otherwise, statistics referring to "Asia" will refer to the entire theater of Asian countries.

It is estimated that between every one in five individuals in Asia (and one in six globally) does not have access to safe drinking water. Numerically, that totals to an estimated 700 million people in Asia and a billion globally. As standards of living rise throughout individual regions within Asia, so will the demand for water along with the likelihood of further internal tensions. Arising water conflicts could cause regional conflicts that may spread to national or international instabilities. Internal conflicts have already arisen in China. One example is in the North China Plains. The national capital has taken control of almost all the major rivers flowing through the Hebei Province due to Beijing's growing population. One exception was the Juma River, which supplied nine cities and 3 million people south of Beijing. In 2006 Beijing moved forward with plans to tap groundwater connected to the Juma River and to raise its dam to collect more water for one of Beijing's water plants. Hebei province officials objected to the plans, but no effective agreement or collaboration has been reached, which has increased local tension.

As part of its rising demand, China's 11th 5-year plan (2006-2011) invested \$87.8B in water projects as part of larger budget of \$204.9B toward environmental improvements dealing with urban infrastructure, industrial pollution, and environmental protection projects (New York Times 2009). Throughout Asia, a major challenge will be to balance the need for both economic and environmental investments with its water demand, population growth, and the need to enforce standards locally to meet the requirements of environmental legislation. International water rights are also becoming more prominent political issues among countries who have historical conflicts. The complex relations governing the vast Mekong River, which is shared by China and its southern neighbors, Myanmar, Laos, Thailand, Cambodia and Vietnam have potential for conflict. While water issues have more often generated cooperation than conflict between nations in the past, demographic pressures and water scarcity could be unprecedented in the coming decades causing normal national ties to be stressed (One World South Asia).

Japan is not a water abundant country; it has suffered from severe water shortages due to its narrow surface area, rapid run-off of precipitation, and high population density. Japan's rapid economic and population growth began in the 1960s. Fortunately, government policies, combined with supporting institutional and legal frameworks and enforcement, seem to have effectively addressed its most severe water shortage problems.

Water trends of concern

Rising demand for water

The forecast for the region is that its population is expected to continue to grow, due primarily to China's growth, which is expected to expand from 1.35 billion today to over 1.41 billion by 2050. Japan's population is in decline and is expected to continue its decline to just above 101 million by 2050. North Korea's population is expected to grow slightly to over 25 million by 2025, but by 2050 it is expected to decline to 24 million (United Nations 2009). South Korea's population is expected to also continue to grow slowly to 52.6 million by 2050. Further discussion of South Korea's population growth is discussed below.

Technology

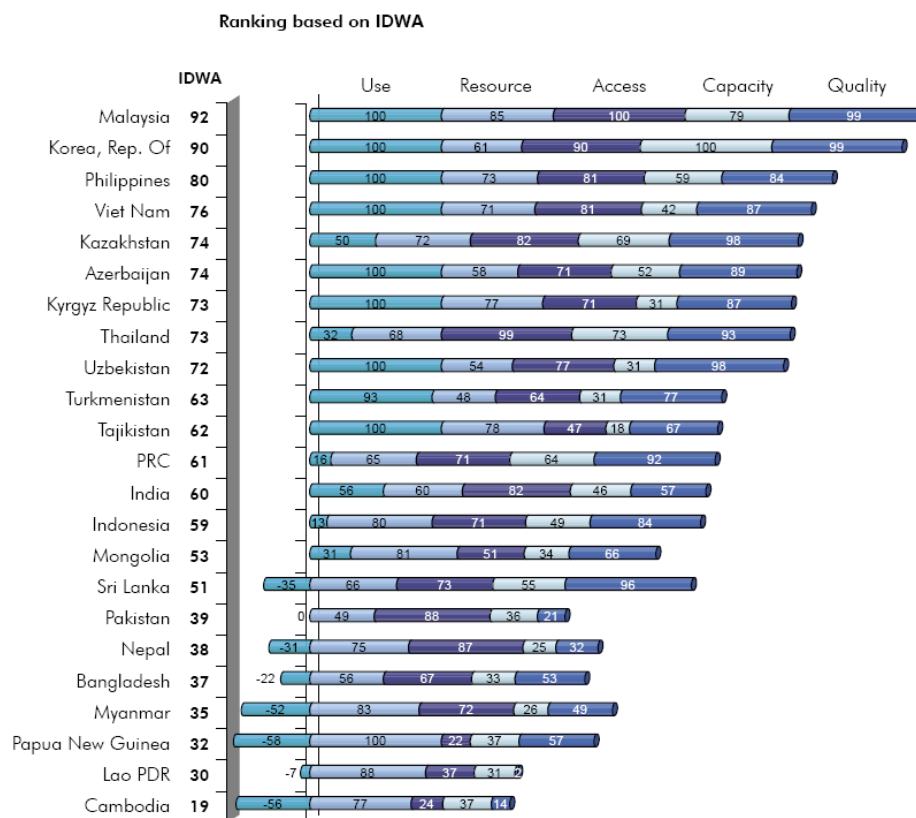
China, Japan, South Korea, and most of Asia have experienced unprecedented economic growth since the 1950s. These countries served initially as sources of cheap factory labor for Western nations beginning shortly after WWII. Japan, South Korea, and now China have and are transitioning to produce increasingly advanced technological products that have helped them transition from 3rd world to primarily 1st world economies in a very short amount of time. China still has large populations with relatively low standards of living, but as whole, China has greatly improved living standards from those of the pre-WWII years. The major exception to the region, North Korea, is controlled by an oppressive military-based regime. Despite receiving aid from China and Russia, North Korea's self-imposed economic and political isolation from Western countries has sometimes wreaked havoc on its civilian population due to lacking infrastructure and its ability to deal with drought or floods.

Water quality

Asia's unparalleled economic growth in the last few decades has allowed severe environmental problems to develop. China's size allows it access to a vast array of natural resources; however its unchecked development aided by local corruption has damaged its environment severely. Acid rain, water shortages, large expanses of water pollution from untreated wastes, and deforestation has resulted in a loss of one fifth of its agricultural lands since 1949 to soil erosion and desertification. Japan and South Korea's growth has stabilized, but acid rain, the result of emissions from power plants, is acidifying its water sources.

Japan is one of the largest consumers of fish and its demand is causing overfishing and stock depletion in its waters and elsewhere. South Korea has more severe water quality issues resulting from unchecked industrial wastes. North Korea environmental problems involve water pollution, water shortages, deforestation, soil erosion, and degradation that has been caused by poorly managed collective lands. Other regions in Asia are experiencing similar if not more severe environmental degradation, however several countries are ignoring environmental concerns over economic goals to reduce poverty by increasing the standard of living for their own countries. Several countries see no reason to change their behavior when they use the United States as an example of success (Walsh 2007).

The Index of Drinking Water Adequacy (IDWA) compares water systems for 23 developing member countries in a manner similar to the Water Exploitation Index in Europe (Figure 21). The elements rated include use, resource, access, capacity, and quality (AWDO 2007). Korea is highly rated in terms of use, access, capacity, and quality however, does not have a large supply of drinking water.



Source: AWDO. Asian Water Development Outlook (AWDO) 2007

Figure 21. Index of drinking water adequacy.

Expected impacts of climate change

Asia has over half the world's population. The effects of global climate change and Asian countries' response to it will impact every other region in world. Although Asia has less fresh water reserves than any other continent, it is imperative that they take collective steps to address their own challenges in response to climate change. Global warming will begin to lessen the water supply in China and India as non-seasonal melting of glaciers in the Himalayas decreases the amount of available fresh water.

Climate change has already begun to affect parts of China and North and South Korea, which have experienced some severe droughts and subsequent water shortages that have evolved into internal conflicts within each nation. Recent extreme flooding in North and South Korea from extreme seasonal rains further exacerbated soil degradation and economic loss.

Similar predictions of increased frequency in extreme weather are expected throughout other parts of Asia as the effects of climate change intensify. More extreme droughts and flooding will occur as glacier retreat and rain-days decrease. Flash floods in mountainous regions are projected to increase and economic impacts to urban areas will become more severe. In 2001, South Korea experienced its worst drought in recorded history (the peninsula received only 30 percent of its average annual rain), causing water shortages for over 16 million people. The same drought caused a famine in North Korea causing an untold number of deaths. Extreme weather like this is anticipated to occur at higher frequencies as climate change continues (Rueters 2001).

Along with China's fresh water shortages, the average rate of sea-level rise was 2.3 ± 0.9 mm (0.09 ± 0.04 in.) per year between 1965 and 1995. Scientist recorded a global sea-level rise of up to 5 cm (2 in.) per year for some regions and local subsidence due to earthquakes and over-withdrawal of groundwater aggravated salt water intrusion. With sea levels expected to rise by up to an additional 0.88 m (over 2 ft) with global warming, it is estimated an additional billion people will be exposed to water scarcity throughout the world due to increased salt water intrusion along many of the coastal aquifers. South-central and Southeast Asia will probably be most affected by the change in water levels (Han, Jianjun, and Wu 1995).

Land use trends

Land use trends in Asia vary between countries. In general, change in land use from open or agriculture to developed land has been increasing over the last several decades.

Land use trends in China moved toward sprawling expansion in the 1990s due to rising incomes of rural households and the desire for improved quality of life. In addition to driving growth of economic capitals such as Shanghai, this trend led to a recentralization of rural villages, that is, development of rural “downtowns.” Previously uncultivated lands that have been placed into production do not make up for the loss incurred by development of previously farmed lands. China’s land per capita (as well as water per capita) is lower than the world average while its demand for land and water is increasing (Yanefski 2010).

India has witnessed commercialization in the agricultural sector due to reduction in overall amount of arable land. The increase in population drives pressure for housing and industry. Input intensive commercial crops have adverse side effects of soil degradation due to erosion, nutrient losses, and compaction, and also cause social distress, as manifested in farmers’ suicides (LUPIS 2008).

Uncontrolled land use change in Indonesia results in deforestation and land conversion from agriculture to non-agriculture lands. The consequent agricultural development of less fertile lands requires increased use of chemical fertilizers and pesticides that ultimately reach the water system. Recent land use trends include a 10 percent reduction in forest area, a 5 percent reduction in paddy fields, and a 13 percent increase in developed lands in the Province of Yogyakarta, Java Island (LUPIS 2008).

More than half of the world’s population currently lives in urban areas. By 2050 it is anticipated that 70 percent will do so, with most of that growth occurring in Asia and Africa. By 2050, one-third of the world’s urban residents will live in Asia. Impacts of increased urbanization on the water cycle include change in surface runoff. In addition, an “urban rainfall effect”—that is, an increase in regional precipitation variability and intensity—has been noted (Seto and Shepherd 2009).

Surface water/containment

Stream flows in South Korea vary largely by season and from year to year, reflecting changing precipitation patterns. Rivers often run dry during the winter months. Dams have been constructed South Korea to control the waters, but are often inadequate. China has invested huge amounts to construct dams to aid in harnessing hydropower and manage river passage. Japan has made tremendous investments in water management construction (dams) and now a majority of its water supplies come from dams. Korea and China are modeling their own efforts on Japan's progress, however where China is building dams as it needs, South Korea is dealing with resistance from environmental and compensatory factions. As water storage becomes more of a necessity to offset diminishing precipitation and erratic weather patterns, South Korean politic may change.

Some unsettling trends are manifesting in China as water scarcity is rising, and river levels are lowering. The 2009 droughts in the Northern and Southern Provinces of China are becoming severe enough that river cargo boat passage is affecting regular commerce on major rivers in the Guangxi Zhuang Autonomous Region. Over 900 cargo ships were stranded along parts of the Xijiang River, creating huge economic effects (Xianzhi 2009).

Flooding

Flooding in the Far East is often the result of monsoon weather patterns and intense alteration of the landscape. Stripping the land of vegetation and channelizing streams reduce the natural system's ability to absorb heavy seasonal rains.

Flooding has recently followed the worst drought in a century in Southern China. Heavy rain claimed 365 lives and caused \$10.4B in damages. The downpours affected 10 provinces that are home to 30 million. Impacts include power outages, damaged roads and railways, loss of crops and homes, and displacement of several million residents.

The worst monsoon rains in 80 years caused widespread flooding in Pakistan in August 2010. The flooding, which lasted 4 weeks, swamped a fifth of the country, claimed 1600 lives, and affected 20 million. More than 3.2 million ha (7.9 million acres) of farmland were damaged in a country's where agriculture accounts for almost one-fourth of the economy. Flooding may have been exacerbated by years of mismanagement with the use of levees, dams, and canals (Inman 2010).

Water conflicts

Most of the regional water conflicts that occur between the Korean Peninsula, China, and Japan are over demarcated lines of fishing rights and territorial disputes over remote islands in the seas between each nation. Up until 1996, where these countries signed the Laws of Open Seas Pact, fishing rights had been heavily disputed. Territorial disputes over islands are still ongoing issues that remain contentious.

Regional conflicts over fresh water usage have mostly occurred between North and South Korea centering on the Yan River, which flows through North Korea to the South. Although the two nations share a water compact regarding water rights with cross border rivers, concern over North's intent has arisen due to a recent un-announced dam release that caused the death of six South Korean campers along the Imjin River. South Korean Officials are concerned that North Korea will use their dams to flood the South Korean basin as an offensive strategy. Such an event could put up to 10 million Koreans who currently live in the lower basins at risk (Jeon-Heon 2009). Prior to this event in 2009, coordination in water management between the two nations has been hampered by ongoing military and political tensions stemming from the Korean War.

Far East water policy

The Asia-Pacific Water Forum (APWF) was created to coordinate water resource management, protect and restore river basins, and reduce the vulnerability of populations to water-related disasters in response to ongoing water issues throughout Asia. The APWF was launched in September of 2006 at the headquarters of the Asian Development Bank* (ADB) (APWF 2009). Although the APWF has no legal authority, it is hoped that ADB support will help fund its efforts to educate and influence Asian governments as they continue to develop. The APWF has sought to establish an effective mechanism to encourage more collaborative efforts on water resources management and to accelerate the integration of water resources management into the socio-economic development process of the Asian and Pacific region.

* The Asian Development Bank (ADB) is the primary organization working to increase investments and support reforms, capacity development, and regional cooperation for Asia and the Pacific region.

Republic of South Korea overview

US Army Garrison Humphreys is located along the southern edge of the Han River Basin in the Republic of South Korea. Issues of concern at USAG-H are: increasing water demand, fluctuating water supply, lack of access to relatively abundant water resources (natural patterns of seasonal and regional water distribution, condition of distribution systems, topography), water quality (non-point source pollution, wastewater treatment), water storage planning, and climate change (temperature rise, increased variability of precipitation).

Water problems are already severe throughout Asia as rapid economic growth and urbanization rates increasingly stress the region's limited water resources. Asia is home to more than half the world's population and has the least amount of available fresh water than any other continent. Climate change is expected to worsen the situation. Experts agree that reduced access to fresh water will lead to a cascading set of consequences, including impaired food production, the loss of livelihood security, large-scale migration within and across borders, and increased economic and geopolitical tensions and instabilities. Over time, these effects will have a profound impact on security throughout the region. For USAG-H, which is undergoing one of the largest transformations in the history of the Army, regional instability is a real threat to mission sustainment.

Geography, topography, and land use

The Korean peninsula extends southward from the northeast part of the Asian continent. The Republic of South Korea covers 98,477 km² (38,022 sq mi), roughly the area of the state of Indiana. The peninsula is bordered by the Sea of Japan to the east, the Korea Strait to the south, the Yellow Sea to the southwest, and the Korea Bay to the northwest. The peninsula is mountainous along the east coast sending river water flowing from east to west and from north to south. The difference in mountain slope—steep eastern slopes and gentle western slopes—results in great regional difference in flood potential. The peninsula has been denuded of most of the ancient Korean forests. Forest loss contributed to flooding and erosion. Cleared by the 1960s, reforestation restored foliage to most of the hills by the 1980s.

In terms of land use, South Korea's predominant cover is forest, which occupies 66.8 percent of the land (Kaen 2009). Cropland covers 21.4 percent and the remaining 12.5 percent is classified other. Under cropland, 19 per-

cent is arable land, 2 percent permanent crops, and 1 percent pasture. Irrigated land comprises 13,350 km² (5154 sq mi), which is 13.5 percent of total land area and 63 percent of all cropland (National Atlas).

Climate

The Republic of South Korea is part of the East Asian monsoonal region and has a temperate climate with four distinct seasons. Winters are usually long, cold, and dry whereas summers are short, hot, and humid. Rainfall averages 1283 mm (~51 in.) —usually between 750 mm and 1000 mm (~30 and 39 in.) — and about two-thirds of the annual precipitation occurs between June and September. These intense summer rains often produce floods and are followed by drought-like conditions during the winter. Summer rains are largely lost to the seas due to the lack of adequate storage basins. Thus, water storage through the winter months is essential.

Precipitation per capita is 30 percent more than the global national average. Despite this high figure, the average South Korean receives only about 10 percent of the world's average per capita annual precipitation. There is generally enough precipitation to sustain agriculture, however serious droughts occur about once every 8 years.

Demographics

South Korea's population has grown rapidly since its inception in 1948. Between 1949 and 1985, South Korea's population doubled from 20 million to 40 million. Population in 2005 was 48.1 million. South Korea has one of the world's highest population densities at 1233 people/sq mi (476 people/km²). Because of its rapid growth, the Korean government began instituting a series of birth control programs. As a result, fertility rates fell from 6.1 in 1960 to 1.21 in 2009. Still, Korea's population is slated to continue to grow to about 49.3 million by 2018 and 52.6 million by 2050 (Korea National Statistics Office 2008). In addition to population size and density, the distribution within South Korea affects its ability to provide adequate water supplies. The capital region of Seoul is home to nearly half of the country's residents.

Water resources in South Korea

Of South Korea's current 34.6 billion m³ (9.1 trillion gal) water supply, 42.7 percent comes from river flow, 46 percent from lake and reservoirs, and 11.3 percent come from groundwater. Sixty-one percent of the overall

supply goes towards agricultural uses, while the public and industry uses 27 and 12 percent respectively (Republic of Korea 2009, MLTM 2008). The dependency on surface water is proving to be a challenge independent of water shortage because South Korea's surface water quality has degraded due to increased industrialization and runoff from agriculture. Its limited water protection policies have done little to limit surface water pollution (Kim, Koh, and Lee 2005). As a result, Eutrophication has become a common problem in reservoirs throughout South Korea and is creating algae blooms the kill off fish stock (Hwang et al. 2002).

South Korea has five water basins: the Han River Basin, the Gum River Basin, the Sumjin, the Youngsan River Basin, and the Nakdong River Basin (see Figure 22). These basins are divided up into 114 watersheds throughout South Korea. Initiatives started in 2001 to build dams for water storage and flood control have been delayed and downsized because of environmental concerns and increased compensation costs. Original 2001 plans to build 27 dams to mitigate with water shortages were downsized in 2007 to nine; however the recent droughts in spring 2009 may shift public opinion towards construction again (Joon-ho and Myo-ja 2009).



Source: www.soeulkoreaasia.com/maps

Figure 22. Humphreys region.

Approximately 13.3 billion m^3/yr (3.5 trillion gal/yr) is available however only 3.7 billion m^3 (978 million gal) was used in 1998, the latest year for which data were available. Aquifers have not been well developed so there is potential for large-scale development on a regional basis.

A number of major dams have been built along the Han River and its tributaries. However, significant urbanization within the basin limits available land area (and thus storage capacity) of reservoirs. Moreover, the Basin is shared between North and South Korea, and although negotiations are ongoing, North and South Korea have not yet reached agreement on joint development of common water resources. Meanwhile, upstream water development efforts are having a negative effect on water quality and availability near Humphreys.

Water shortages are more extreme in some parts of Korea than others. The Han River basin, located along the border between North and South Korea, is considered the heart of Korea and has 41 percent of South Korea's population. Despite the Han River being known for its huge coefficient of river regime (ratio between the maximum and minimum amount of flow) of 1:390, the Han Basin is well supplied with water by a number of dams along the river; no shortages are expected.

However, the southern portion of South Korea is faced with a significantly different situation. This part of South Korea receives less rain and has less storage capacity for water in its reservoirs (MLTM 2008). According to the Korean Water Resources Corporation (K Water), in 1998, South Korea's total water demand was 33.08 billion m^3 (8.7 trillion gal) and its supply was 33.11 billion m^3 (8.7 trillion gal). Since then, its demand has risen dramatically due to the country's urbanization and industrialization.

K Water forecasts that the national water demand will increase to 37.0 billion m^3 (9.7 trillion gal) by 2011, exceeding water supply by 3.92 billion m^3 (1 trillion gal). Korea's average water demand has increased by 1.6 percent a year since the mid 1990s; after 2011, it is expected to continue to increase by 0.2 percent per year based on adjusted water management initiatives. However, the water management initiatives may not be enough, thus K Water believes the only way to address the water shortages is dam construction for storage and multi-regional sharing and demand management (Dong 2009). Korea's water demand is expected to continue to increase to the point where it will potentially create a shortfall of about 5 billion m^3 (1.3 trillion gal) by 2016 (MLTM 2009).

With the increased water demand due to rising standard of living along with a growing population, South Korea's water supply issues are expected to become more severe. Demand is forecast to exceed supply by 2011 due to the southern regional shortages. The north region, where the Han River is located, is expected to remain stable with regards to water supply, however, since South Korea shares this river with North Korea, potential conflicts may threaten the stability of this source as North Korea becomes drier (Cho 2009).

Catchment and storage

Storage is a key component of South Korea's water management portfolio not only in response to seasonal variation, but also to ameliorate the impacts of year-to-year fluctuations. South Korea's total annual precipitation fluctuation can be extreme, resulting in very high flow variation in rivers. South Korea currently makes use of about 26 percent of its available precipitation through catchment and reservoirs before it flows out to the ocean or evapo-transpires. The monsoon-drought cycle results in the loss of approximately 52.2 billion m³ (1.3 trillion gal) of water lost during the flood period. The coefficients of the river regime expressed by a ratio of maximum discharge to minimum discharge for Korean rivers usually ranges from 300 to 400, which is far greater than 10 to 30 for major rivers of the world (Ministry of Construction and Transportation 2005). This causes serious problems in river management including flood control and water use.

The multi-purpose dam program was conceived in 19XX. Among its goals were water supply, flood control, hydropower, navigation, recreation, and wildlife conservation. The Soyanggang Dam was the first constructed in 1973. Since then fourteen more dams have come on line for a total of 13 billion m³ (3.4 trillion gal) water storage and 1041 MW (3.6 billion Btu/hr) power capacity.

According to K Water, a private company that manages South Korea's national water supply, the primary cause of water shortages is South Korea's inability to store enough precipitation with existing dams, along with the rapid increase in demand caused by increased standards of living (K Water 2007).

South Korea is heavily dependent on its ability to store and distribute surface water. Uncoordinated management, falling precipitation levels, and exponentially growing demands combine to create a dismal outlook for water resources. It behooves South Koreans to identify and deliver tools for effective water management that will solve the existing problems and eliminate future supply vulnerabilities.

Water quality

Securing safe water supply sources is one of the Republic of Korea's (ROK) most critical challenges for the 21st century. The country's reliance on rivers as the primary source of drinking water represents a challenge given the degradation of water quality. Korea experiences water quality problems of elevated biological oxygen demand (BOD) concentration, eutrophication, and non-point source pollution (Kim, Koh, and Lee. 2007).

The ROK Government established comprehensive water quality measures for the four major river basin areas: the Han River (affecting 20 million people) in 1998, the Nakdong River (affecting 13 million people) in 1999, and the Geum and Wyongsan Rivers (affecting 7 million people) in 2000 (Ministry of Environment 2004).

Expected impacts of climate change

South Korea has already experienced changes in climate over the last century thought to be impacts of broader climate change. Temperatures have increased 1.5 °C from 1905 to 2005. This compares to a global increase of 0.74 °C. The Korean peninsula recently experienced the worst drought since records began over 100 years ago. In 2001, over 16 million people suffered water shortages when precipitation totaled only 30 percent of the average annual amount. At the same time, South Korea is experiencing increasing numbers of extremely hot days. Average temperature is projected to increase by 5 °C by the end of the century (Jang et al. 2003). Annual precipitation has increased from 1166 mm to 1501 mm (~46 to 60 in.) between 1920 and 2006.

The Intergovernmental Panel on Climate Change projections contain a range of conditions that could affect continued reliability of the water supply to the Korean peninsula. South Korea is expected to experience more extreme swings in weather with regards to droughts and rain fall. Rain events are expected to decrease while individual storms are expected to become more intense, increasing the potential for flash floods. The increased intensity is expected to provide an overall increase in precipitation, but the likelihood for flash floods and severe typhoons is expected to increase. As Korea has a limited number of dams and reservoirs to mitigate flash floods, economic damage is expected to increase. Much of the precipitation will be lost to the ocean due to insufficient storage. As the rain events become less frequent, the southern portions of the country will become drier and the frequency of drought will likely increase. The fore-

cast is that demand will exceed supply in all regions by 2011 (MLTM 2008). The north region, where the Han River is located, is expected to remain relatively stable with regards to water supply, however, North Korea shares this river with the South and conflicts may threaten the stability of this source as northern parts of North Korea are expected to become drier (IPCC 2007).

Precipitation is projected to increase another 15 percent by the end of the century. Continued seasonal swings in precipitation are anticipated along with greater intensity storms. While the number of rain events is expected to decrease, the severity of individual rain events is expected to intensify, increasing the potential for flash floods. The increased intensity may provide equivalent overall rainfall, but as temperature rise continues, the overall rainfall will continue to decrease. Economic damage is expected to increase as Korea has a limited number of dams and reservoirs to mitigate flash floods. Much of the precipitation will be lost to the ocean due to lack of storage. As rain events become less frequent, the southern portions of the country will become drier and drought occur more frequently.



Figure 23. The Republic of Korea (South Korea).

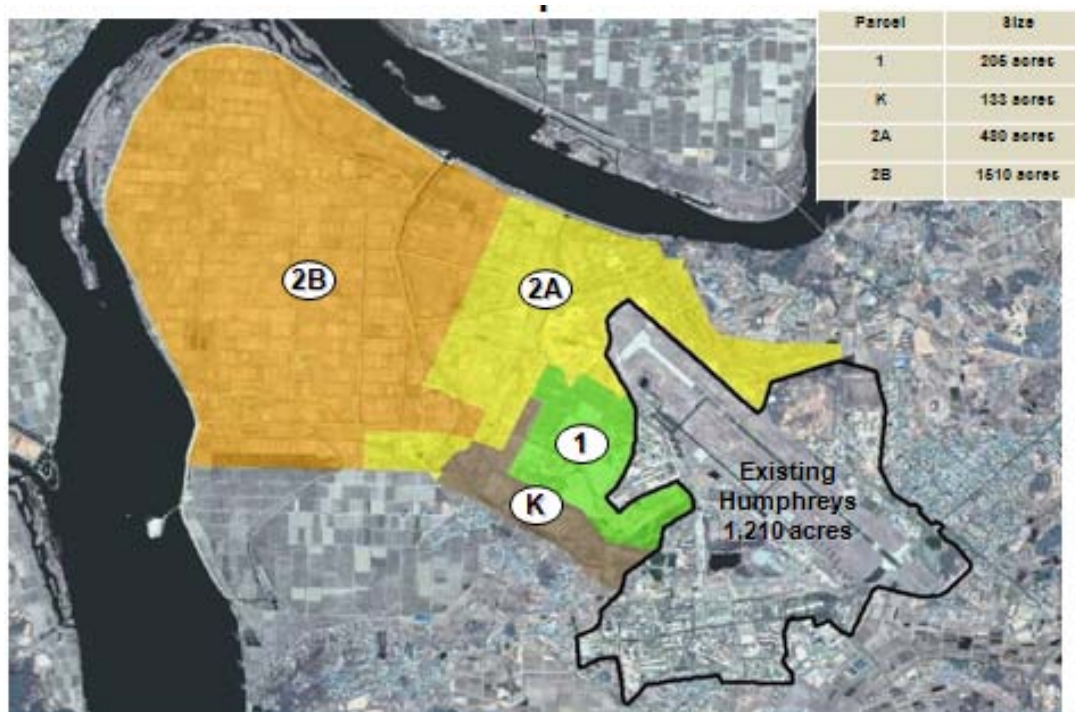
Water policy in South Korea

Historically, South Korea's water management began as a product of legislation developed during South Korea's foundation in the 1950s. Multiple national agencies were put in charge of different aspects of water management. Their efforts and jurisdiction are uncoordinated, and as a result, one agency's policies can contradict another's. Most of the contradictions occur between the Ministry of Environment, which manages the drinking water supply and the Ministry of Construction and Transportation, which manages surface, groundwater, and reservoir supply. In 2005, South Korea proposed the Water Management Act to coordinate these two agencies at a Federal level while directing water management to be driven by local government (Kim, Koh, and Lee 2005). The Act would have also provided for the preparation of a national integrated water resources management plan and established basin commissions and a national water management commission. However, the Act did not win approval in the National Assembly in 2008.

The primary water action has come from the Ministry of Construction and Transportation through the establishment of wide-area water supply facilities. A wide-area water supply facility provides purified water to at least two local communities that have suffered from a poor water supply system. It helps provide a large amount of water to a number of districts, and ensures a sustainable water supply for those districts. Moreover, it helps address the water supply imbalance between the districts. A basic guideline on wide-area water supply was completed in 2003, dividing the nation into 12 districts based on the proximity to water facility and connection to the supply system. Multipurpose dams are being planned and constructed in different zones of some rivers and others are scheduled to be included in the near future. Through these efforts, more water can be provided to water-stressed areas, which will contribute to resolving the imbalance of water supply among areas and to providing stable water supplies even in emergencies, such as drought.

US Army Garrison Humphreys

US Army Garrison Humphreys (USAG-H) is located in the most populous province in South Korea, Kyonggi-do. Korea's largest city and national capital, Seoul, is located in the heart of the province. Nearly 19 million people reside in Kyonggi-do Province, 10 million within Seoul. USAG-H is located on the very southern edge of the Kyonggi-do Province, about 48 km (30 mi) south of Seoul (Figure 24).



Source: USAG-H Master Planning
Figure 24. USAG-H future expansion.

USAG-H is also located just inside the Han River Basin that has 25.5 million inhabitants within its borders (Figure 24). The garrison is located just east and south of Asan Bay and the Ansung River before it reaches Pyeongtaek to the east. The Ansung River flows from east to west towards the West Sea. Just outside the USAG-H gate is the small town of Anjung-ri with approximately 5000 people. The nearest metropolitan city, Pyeongtaek, is 16km (10 mi) to the east. The area immediately surrounding USAG-H is currently rural farmland with some low lying hills. The local area elevation is generally below 45.7 m (150 ft), with the garrison elevation at approximately 4.6 m (15 ft) above sea level (Harrelson et al. 2007). Much of the farmland will soon be replaced as USAG-H undergoes a large garrison transformation. (It has been chosen as the new site for the 8th Army Headquarters.) USAG-H facilities will grow from approximately 370,000 to almost 2.79 million m² (4 million to 30 million sq ft) by 2020 and the overall garrison will more than double in area. The garrison population of 5200 in 2008 may grow to up to 56,000 by 2020 with tour norm stationing (USAG-H Master Planning 2009). With the expansion, USAG-H has acquired approximately 971 ha (2400 acres) of adjacent farmland to the northwest between the installation and the Ansung River.

Prior to the relocation of the 8th Army Headquarters, the USAG-H primary mission was a troop movement through Desiderio Army Airfield, along

with housing support, transportation, and tactical units. Due to the headquarters relocation, USAG-H will become the flagship US Army installation in South Korea and the headquarters for all Army tactical operations in theater. The 2020 end state population is forecast at nearly 20,000 troops, 26,000 dependents, and 7000 civilian contractors. However, the influx of soldiers and dependents, and the services and support facilities will expand dramatically prior to that time to accommodate the potential for over 50,000 people.

Region of analysis

The boundaries for this analysis include all the potential sources of water for USAG-H. This includes the existing wells and the water sources in the Han River Basin. As reported from the USAG-H staff, Pyongtaek's municipal water supply is comprised of 90 percent from the Paldang Reservoir and 10 percent from the Ansung River that flows next to Pyongtaek and USAG-H. As the municipal resources rely heavily on the Paldang Reservoir, this regional analysis will focus on the Han River Basin. Therefore, any significant limiting factors should be addressed as they might affect the Paldang Reservoir rather than the Ansung River. Also, if any local shortages were to occur with the Ansung River, it is likely the Paldang Reservoir would fill shortfalls to the garrison (Figure 25).

Regional water management factors

USAG-H lies just within the Han River Basin along the Gum River Basin border. The Han River Basin is shared between the Republic of Korea (South Korea) and the Democratic People's Republic of Korea (North Korea). Even though water rights have been set, South and North Korea have not yet reached agreement on joint development of this common water source, although negotiations are ongoing. Meanwhile, upstream water development efforts sometime have an adverse effect on water availability in the south. North Korea has built huge dams and reservoirs along the Han River, ignoring the environmental impacts further downstream. With the ongoing political conflict, the hydrological property of the basin has not been studied fully. However, the United Nations estimates the renewable water resources in the Han Basin are 16 billion m³ (4.2 trillion gal) with 8.5 billion m³ (2.2 trillion gal) available for use by 2003 (WWAP 2009). The relative water availability is comparable to the Ministry of Land, Transport and Maritime affairs estimates of 58 percent of available water supply (MLTM 2008).

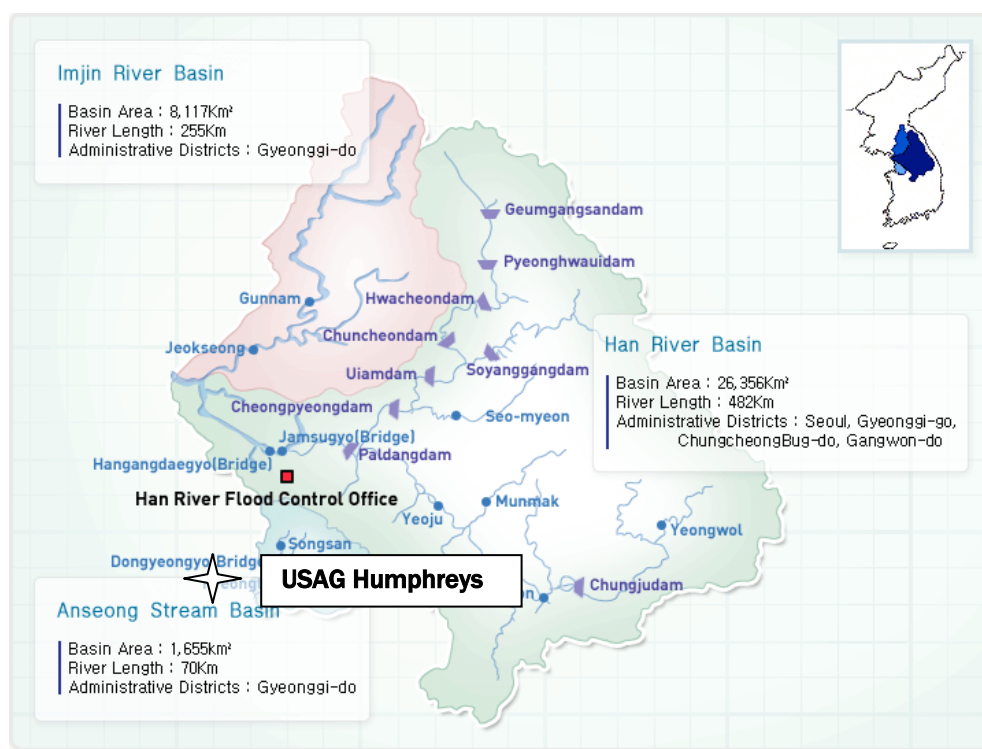
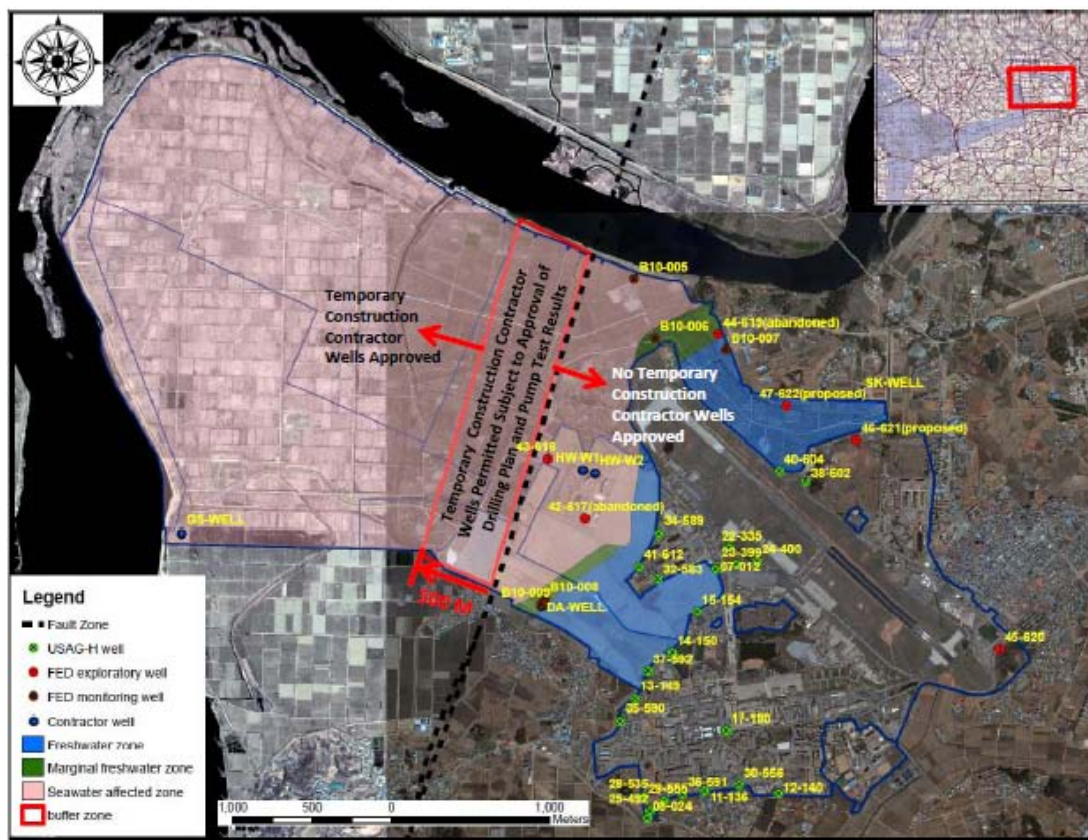
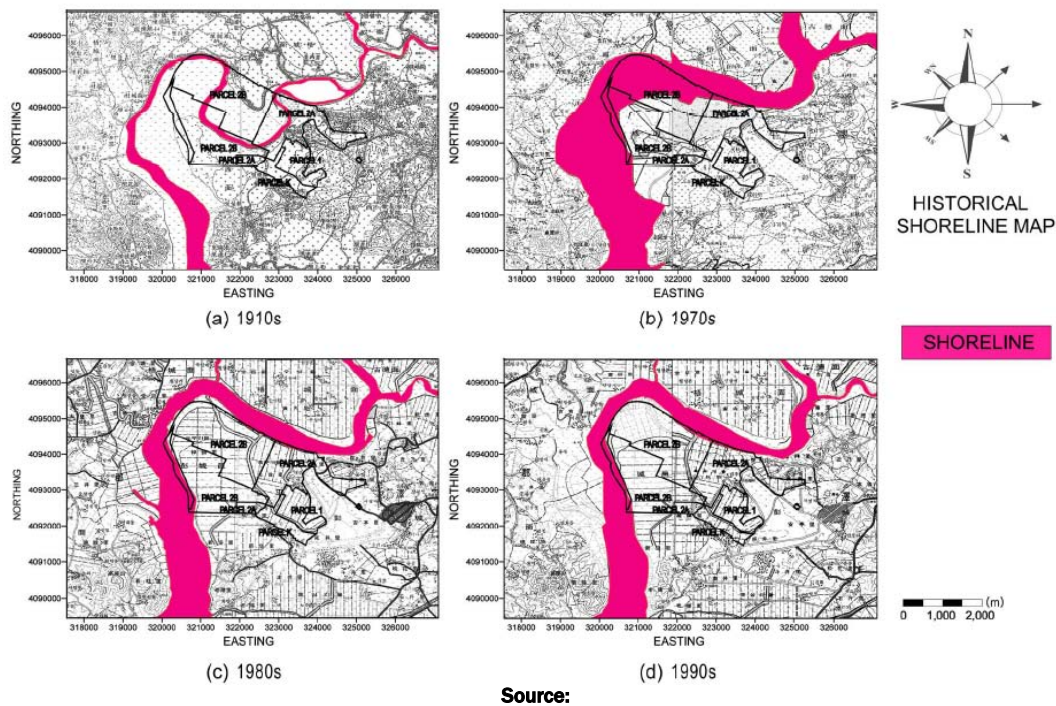


Figure 25. USAG-H water study region of analysis.

USAG-H currently supplies its own water through wells located within the garrison. However, the installation is located over an igneous rock layer that limits additional drilling within 500m of current wells due to draw-down. Unfortunately, the expansion area is located over the former river bed of the Anseong River (Figure 25). As a result, test wells expecting to increase groundwater sources for the garrison found this water too saline for use. Just west of current USAG-H borders, a fault line coincides with the salt water transition to fresh water and permits sea water to infiltrate the soil under the expansion area. Existing wells near this fault line have total dissolved solid (TDS) values between 500 and 1000 mg/L (500 and 1000 parts/million) and are considered marginal in fresh water quality. Aquifer assessments reports by the Far East Geotechnical and Environmental Engineering (GEE) Branch strongly recommend avoiding further drilling east of the fault line to prevent additional drawdown and saltwater intrusion from reaching current fresh water wells. Exact procedures are detailed in their report. The GEE Branch recommends annual testing as saltwater intrusion into existing wells is still possible. (Figures 26 and 27).



Population within the Han River Basin is anticipated to grow from 25.5 to 28.5 million until 2040, when the population is expected to level. Local area population growth trends in relation to Pyeongtaek are difficult to gauge because its city borders were expanded in 1995 to include Osan, a city of approximately 70,000. Accordingly, Pyeongtaek's population grew by 107,300 from 1990 to 1995. City data show a population peak in 2006 of 406,000, but a drop to 402,000 in 2007. In addition, recent city history shows several municipal names and border changes in the metro area. Therefore, attempting to accurately forecast the future population of Pyeongtaek is challenging. Regardless, the overall trend for Kyonggi-do Province is for growth due to the job opportunities in Seoul, tourism, and its accessible ports (Pyeongtaek City 2009).

Water supply model

The USAG-H existing water supply consists of 26 groundwater wells, with 23 located within the installation's existing perimeter. Current 16-hr running capacity is estimated at 4428 m³/day (1.17 MGD). However, as municipal connections are made due to USAG-H expansion, the existing deep wells will serve as a supplement to the city water supply and as an alternate supply in the event of emergency (Park 2009).

Municipal supply will come through Pyongtaek's system, which receives 90 percent of its water through Seoul and 10 percent from the Ansong River. Seoul acquires its water supply from the Paldang Reservoir on the Han River. The Paldang Reservoir supplies water to approximately 20 million households. The reservoir is not only the source of water supply for the city of Seoul, but also for several suburban portal cities, and Kyonggi-do provincial areas as far south as Pyongtaek and as far north as Uijongbu (Ahn 2000). The Paldang Reservoir is located about 48 km (30 mi) east of Seoul. Its source, the Han River, supplies an additional 5.5 million residents within the basin's borders. As such, USAG-H will essentially be sharing its water supply with approximately 25.5 million South Koreans. USAG-H wastewater will be pumped to the Paengsong wastewater treatment plant located off garrison and just outside Pyongtaek on the Ansong River (Davis and Jung-il Associates 2006). South Korean wastewater is typically treated and pumped back into their river system. As such, Paengsong is expected to pump the garrison wastewater into the Ansong River that flows out to the sea. Therefore, no calculations were done using wastewater as a source of re-supply to the garrison aquifer (Figure 28).

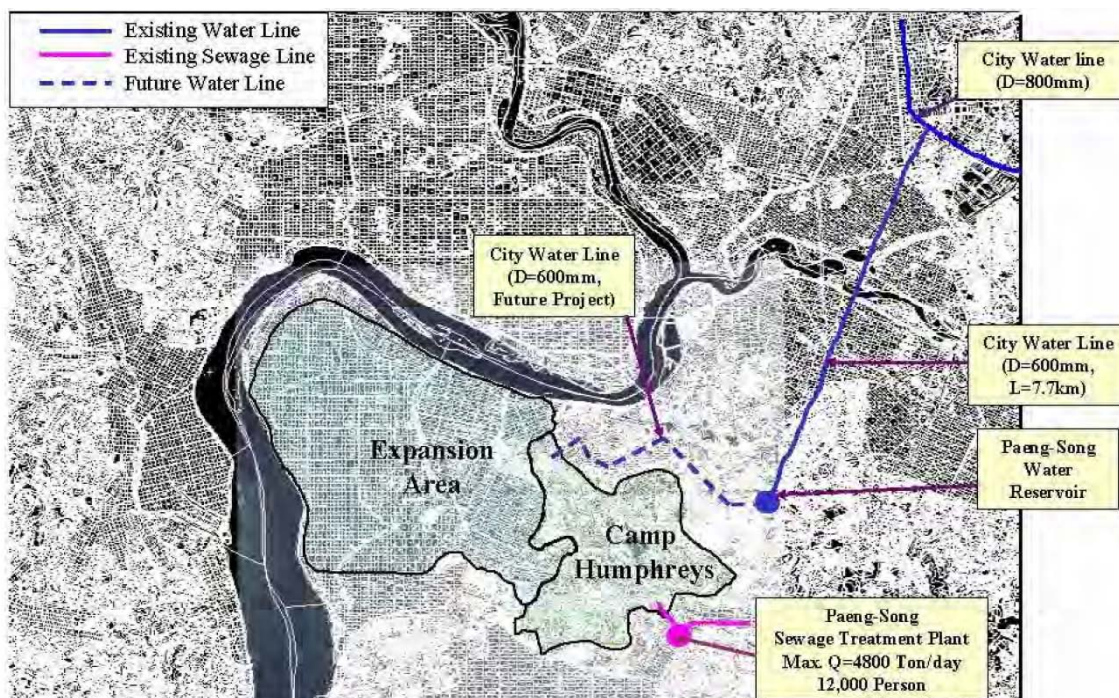


Figure 28. New water and waste water supply system.

Supply factors

As mentioned, current water supply is primarily from groundwater wells. As the garrison transitions, future water supply may or may not come strictly from Pyongyang's municipal supplies. Since Pyongyang's primary source is the Han River, this discussion includes multiple factors relating to the Han River Basin as they are taken into account for planning scenarios. These scenarios reflect both forecast supply and demand. The 2009 baseline regional demand estimates are from the Ministry of Land, Water and Maritime (MLWM) 2002 forecast of 2011 water supply and demand estimates for the Han River Basin. Supply for the entire basin was interpolated in 2009 to be 21 million m³/day (5579 MGD) and demand to be 24 million m³/day (6408 MGD), for an overall basin deficit of 3 million m³/day (829 MGD) (Table 9). Garrison demand used in the scenarios was obtained primarily from 100-percent demand model scenarios, except for one scenario where garrison demand was derived from the 80 percent relative size end state. Every scenario incorporates the EO 13514 water conservation requirements. South Korea has plans to build additional dams to increase their water storage and availability of water. However, projections for additional storage supply cannot be projected since several of the planned dams have been canceled and adjusted in capacity. Current Korean water storage capacity estimates that only 58 percent of the potential water available is being used (MLTM 2008).

Table 9. Planning scenarios for USAG-H.

2040 Planning Scenarios		Water Balance in 2040 with EO 13514 implemented					
		1	2	3	4	5	6
USAG-H Region	2009 Baseline	Moderate Clim Chg	No Climate Chg	Extreme Increase	Water Efficiency	Worst Case	80 %
Han River Basin							
Natural Recharge	5579.2	6,322.8	6,021.7	7,286.2	6,322.8	5720.6	6322.8
Han Basin Population Demand	-6408	-8138.1	-7176.9	-9099.3	-8138.1	-8650.7	-8138.1
USAG-H Demand	-0.6	-7.2	-6.3	-8.2	-6.0	-7.2	-6.1
Humphreys' Aquifer							
Natural Recharge	1.2	1.3	1.2	1.5	1.3	1.1	1.3
USAG-H Demand	-1.2	-1.2	-1.2	-1.2	-1.2	-1.2	-1.2
Total Water Balance (MGD)	-829	-1822	-1162	-1821	-1821	-2937	-1821
USAG-H Total Demand (MGD)	-1.8	-8.4	-7.5	-9.4	-7.2	-8.4	-7.3
Annual 2040 Cost (M\$)*		11.7	10.4	13.0	10.0	11.7	10.1
Price Difference from Scenario 1			-1.3	1.3	-1.7	0.0	-1.5
*Unit Price =\$3.80							

Aquifer

Aquifer scenarios regarding existing wells were not explored due to the assumption that if the groundwater were to suddenly become too saline, then the supply would be switched to municipal sources. An estimate for the potential recharge of the aquifer beneath the installation expansion area is 15.1 million m³ gal/yr (4 billion gal/yr) (Harrelson et al. 2007). However, due to the infiltration of sea water from the fault line, much of this is saline (cf. Figure 27). According to the saltwater intrusion study:

Investigations have revealed a previously unknown saltwater intrusion condition that basically makes it infeasible to drill any production water wells within the entire land development area, except possibly within a limited portion of Parcel 2. A north of the existing runway and the extreme eastern section of Parcels 1 and K. (GEE Branch, USACE District, Far East 2010)

The largest threat to the existing wells is saltwater intrusion developing from excessive drawdown created by over pumping. Limits to the existing well capacities will be based on water quality, not quantity. Each of the scenarios reflect source distribution based on continued use of the existing wells at USAG-H, with increased demand offset by supply provided through the local municipal system (Table 10).

Population growth

Besides the garrison growth, the population in the Han River Basin is expected to grow by 12 percent, from 25.5 to 28.5 million, by 2040. Therefore, this increased demand of 12 percent by 2040 is reflected in all of these scenarios, with the exception of Scenario 5, which includes an increase in demand of 20 percent.

Table 10. Scenario planning factors.

Scenario						Factors
1	2	3	4	5	6	
Han River Basin						
-2%	-2%	-2%	-2%	-2%	-2%	Decrease in usage to 2020 due to EO 13514 implementation
5%	0%	21%	5%	-5%	5%	Increase/decrease in natural recharge
12%	12%	12%	12%	20%	12%	Increase in demand due to population
15%	0%	30%	15%	15%	15%	Increase in demand based on higher temperatures
USAG-H Aquifer						
-2%	-2%	-2%	-2%	-2%	-2%	Decrease in usage to 2020 due to EO 13514 implementation
5%	0%	21%	5%	-5%	5%	Increase/decrease in natural recharge
15%	0%	30%	15%	15%	15%	Increase in demand based on higher temperatures

Climate change and changing precipitation

Trends in the northern regions of South Korea reflect an overall increase in precipitation. Northern regions show an increase in precipitation in June between 18–180 percent in the last 6 decades, with a decrease between 15–74 percent in April. Changes in precipitation have strong spatial correlation, which means lower spring precipitation patterns will likely result in extreme storm events later in the summer season (Bae, Jung, and Chang 2008). According to the Intergovernmental Panel on Climate Change (IPCC), overall precipitation in South Korea is expected to increase between 15–21 percent in the next century. Through 2040, this equates to a 5–6 percent increase in overall precipitation. IPCC forecasts a gradual increase in temperature between 1.5–1.8 °C through 2040. However, after 2040, future decades are expected to increase in temperature and precipitation faster, with a potential increase of 6.95 °C and 21 percent precipitation by the end of the century (IPCC 2007).

For these scenarios, moderate climate change was classified as an increase in overall precipitation of 5 percent by 2040 and extreme climate change as an increase of 21 percent to reflect the century end scenario. Also added were factors reflecting increase in demand for cooling, and irrigation needs resulting from increased regional temperature. The IPCC states that demand will increase in regions as the average temperatures rises due to the needs for additional manufacturing cooling, irrigation to offset increase evapo-transpiration rates, and lower crop yields. As temperatures continue to rise, crop yields for rice and wheat may decline from 10–30 percent in parts of Asia (IPCC 2007).

Climate change as applied to the scenarios

- Scenarios 1, 4, and 6 reflect moderate climate change with an increase of 5 percent for precipitation and an increased demand of 15 percent for cooling and irrigation.
- Scenario 2 reflects no climate change and, thus, no change in precipitation or demand for cooling or irrigation. However, it does reflect growth in demand due to increased population.
- Scenario 3 reflects extreme climate change with an increase in precipitation of 21 percent with an increased demand of 30 percent.
- Scenario 5 reflects a worst case scenario where climate change does not increase, but instead decreases precipitation. This scenario reflects a decrease in precipitation of 5 percent by 2040, but retains an increase in demand due to population growth and increased temperature.

Water demand model

As mentioned, the Paldang Reservoir supplies water to approximately 20 million households. The reservoir is the source of water supply for the city of Seoul, for several portal cities in Kyonggi-do province, and for areas south to Pyongtaek and north to Uijongbu (Ahn 2000). Demand along sections of the Han River previously regulated by K Water are now regulated by multi-regional agencies to ensure that water quality and demand upstream do not endanger the Paldang water quality. Ratings of the reservoir have been poor, but recent government initiatives have strived to improve water quality (K Water 2009). Regional demand amounts were obtained from the Korean Ministry of Maritime and Land Transportation Management (MLTM). This agency had the most recent estimates of regional and future demand for the Han River Basin. Current estimates by MLTM state that the Han River Basin regional demand will outstrip supply by 40 billion tons 34,000,000,953 m³, or 8.98 trillion gal) by 2011. The deficit is expected to increase to 170 billion tons (144.5 billion m³ or 38.2 trillion gal) by 2020. This increased demand is matched against this regional forecast supply scenarios to determine overall water deficits expected for the region by 2040.

Overall demand was forecast for USAG-H through 2040 by calculating estimates derived from the expected Master Planning tour of normal populations. With expected static population after the 2020 end state, daily demand is expected to be 33,687 m³/day (8.9 MGD) by 2020, extending to 2040, without integration of EO 13514. With the required 26 percent reduction in water use by 2020, demand is estimated to be 28,388 m³/day

(7.5 MGD) when the end state population stabilizes in 2020. This reduced estimate does not factor in climate change influences on demand. Another demand scenario (i.e., Scenario 6) was created in which the 2009 plan forecasts of end state populations are reduced to 80 percent of their projections, giving an expected demand without conservation at 29,523 m³/day (7.8 MGD), and 24,603 m³/day (6.5 MGD) with the implementation of EO 13514. It should be noted the planned new golf course will be irrigated primarily by captured rain water.

Figure 29 shows the 100 percent end state population projection, in which USAG-H could save approximately \$2.5 million per year (i.e., the difference between \$13.1 million of column 1 and \$15.6 million of column 3) by integrating EO 13514 conservation requirements, assuming it were to rely solely on the municipal water supply. This estimate is based on a \$4.80 per 1000 gal (3780 L) unit price for USAG-H in 2010 (IMKO-PWD-O 2010). If the garrison were to combine municipal and local well sources, their average unit price would be approximately \$3.80. Annual estimates for water costs combining these sources would be \$12.4 million per year based on 33,687 m³/day (8.9 MGD) without water conservation incorporated (Figure 29, column 2).

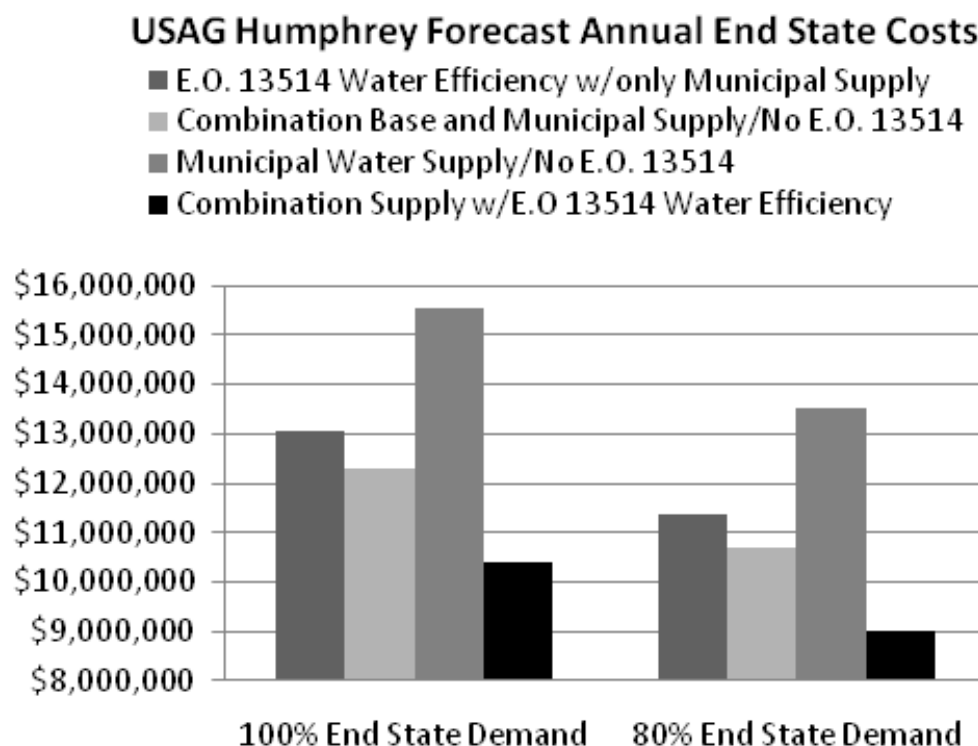


Figure 29. Forecast annual cost based on end state status.

Using a combination of municipal and local well sources while incorporating EO 13514 results in \$10.4 million in annual costs. End state population projections at 80 percent show similar projections of water sourcing in Figure 29. In this scenario, 29,523 m³/day (7.8 MGD) at the projected \$4.80 per 1000 gal (3780 L) is expected to cost approximately \$13.5 million annually.

Water demand factors

Extent of growth

Ongoing planning and designs for construction of the new USAG-H are undergoing constant changes and adaptation. With this understood, one can assume that further changes and designs may well be considered after this report is written. These estimates assume the current 2009 Master Plan will continue to be in effect, with the understanding that funding and changing mission needs may curtail or increase water demand in the future. Given this uncertainty, the factors that increased demand in this model were based on forecast square footage, personnel based from 2009 personnel numbers, and housing units provided by the USAG-H Master Planning Office. An estimated end state of 4630 tour-norm housing units was derived from the 1-N Projected Facilities worksheet (USAG-H Master Planning 2009). Barrack numbers were obtained from the 2007 Yongsan Relocation Program (YRP) Master Plan summary that detailed 10,391 units.

Square footage

This model provides projection factors that can be calibrated based on installation input reflecting the relative growth of major facility types. As such, the estimated increase in overall square footage was used to increase these factors accordingly to reflect each sector's projected growth. Square footage estimates were provided by the 2006 YRP Master Plan Executive Summary (Davis and Jung-il Associates 2006).

Construction criteria

Exact building criteria for new construction was not clarified in either master planning documents or site visit conversations. Current building and consumption estimates are based on historical usage standards. LEED building criteria would significantly shift overall demand projections downward. However, until clarified, recommendations will include integration of LEED 3.0 at the earliest opportunity, if it is not already in place.

Personnel

A tenfold growth from 5000 to over 50,000 shows not only change in size, but type of population that will inhabit the garrison. Resident family population was based on the tour norm numbers estimate obtained from the Master Planning office of USAG-H. The overall estimate includes approximately 17,000 soldiers, 26,000 family members living on garrison, 2100 South Korean soldiers, 3800 contractors, and 7700 civilian contractors (USAG-H Master Planning Spreadsheet 2009). The water demand for non-resident contractors and South Korean civilian personnel was multiplied by one-third to reflect 8-hr workdays.

End state

Full end state for USAG-H, including tour norm estimates, is expected to have over 26,000 family members, 17,000 troops, 10,400 barracks, 4600 housing units, and over 7700 contractors. Although exact numbers are unknown, this demand model end state is based on these personnel and housing amounts. Figure 30 shows the end state demand of 33,687 m³/day (8.9 MGD) compared to a potential end state demand that assumes the integration of a 26 percent reduction in water use as directed by EO 13514. The incorporated water efficiency creates a demand of 28,388 m³/day (7.5 MGD). If USAG-H does not fully expand to the 2009 end state projections, but rather only 80 percent of the projected level, it is estimated that overall demand will be reduced to 29,523 m³/day (7.8 MGD) without water conservation and 24,603 m³/day (6.5 MGD) with water efficiency (Figure 30).

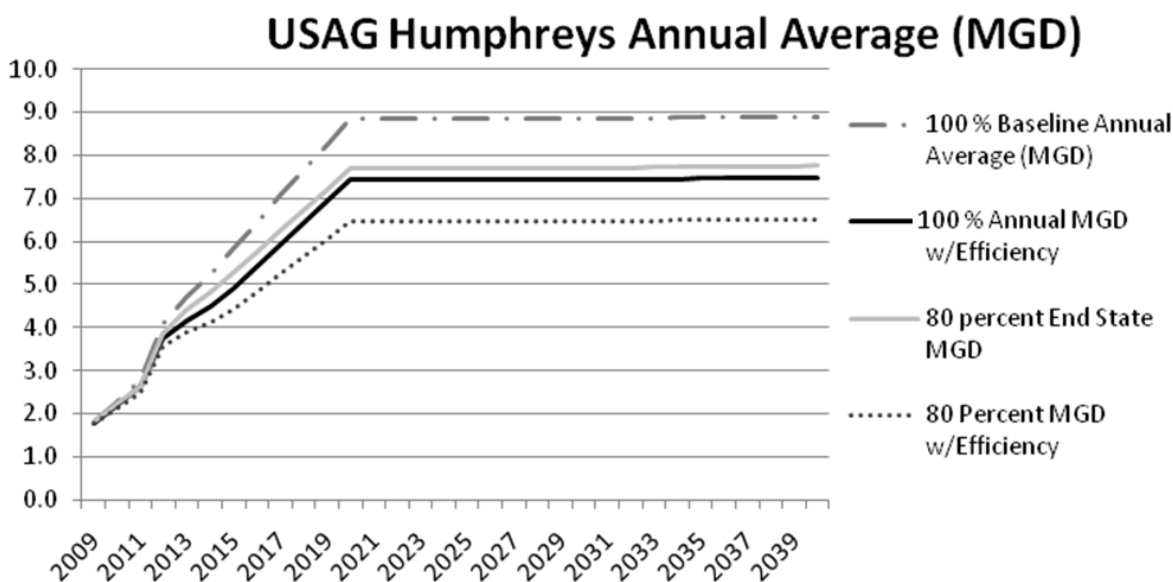


Figure 30. USAG-H forecast demand to 2040 at 80 percent end state.

Future water scenarios

To see how different climate and policy choices may affect overall water supply to USAG-H and its surrounding region, the scenarios were compared to reflect the overall water balance expected in 2040. Comparative pricing was also computed to provide a relative estimate of how various practices may potentially save costs using a mixed source unit pricing of \$3.80 per 1000 gal (3780 L). The price estimates are not meant to forecast actual costs, but to serve as comparison only (Table 9).

*Baseline Results*Scenario 1. Moderate Climate Change

An increase of 5 percent precipitation was factored into Scenario 1, along with an increase in demand of 15 percent for rising temperatures and population growth of 12 percent. These increases in demand, population, and precipitation reflect estimates from the IPCC data and the Korean Statistical office.

Scenario 1 Results:

The forecast balance deficit of demand to supply by 2040 is estimated at 6.9 million m³/day (1821 MGD). With this moderate climate change, USAG-H water demand is expected to increase to 31,794 m³/day (8.4 MGD), compared to this demand model's initial estimate of 28,387 m³/day (7.5 MGD). The comparative cost is estimated at \$11.7 million annually.

Scenario 2. No Climate Change

Climate change is widely accepted as the likely outcome of long term temperature and precipitation trends. However, this scenario reflects a status quo in regional and garrison demand. Therefore, this scenario does not factor in the possible increased demand resulting from rising temperatures or increased supply from increased precipitation caused by climate change. However, this scenario takes into account increases in demand due to population growth.

Scenario 2 Results

The resulting water balance expected in 2040 reflects a lowered regional water deficit of 4.4 million m³/day (1162 MGD). As expected, USAG-H demand remains at 28,388 m³/day (7.5 MGD). Annual comparative costs are \$10.4 million.

Scenario 3: Extreme Climate Change and Increased Precipitation

Neither moderate nor extreme climate change is desired, but is expected in some regions more than others. The extreme scenario for USAG-H is based on the potential increases in temperature (6.95 °C) and precipitation (21 percent) expected by the end of this century, but forecast for 2040 populations, assuming a proportional increase in water demand for increased cooling, evapo-transpirations rates, and lowered crop yields. This scenario assumes a 21 percent increase in precipitation, a 30 percent increase in demand due to temperature, and 12 percent population growth.

Scenario 3 Results

Extreme increase in demand seems to be offset by higher recharge, with a nearly identical 6.9 m³/day (1821 MGD) deficit compared to Scenario 1. In this context, USAG-H demand is expected to increase to 35,579 m³/day (9.4 MGD) from 7.5 MGD, with annual comparative costs rising to \$13 million. This is the most expensive of all scenarios due to the increased demand.

Scenario 4: Total Water Management Policy

The Pacific Institute, a water conservation group, estimates that a comprehensive water conservation program has the potential to reduce current water use by up to 40 percent. This program includes water re-use technology, high efficiency fixtures, and limited irrigation. They estimate a comprehensive water conservation program could be implemented in a community within 2 years. Increased conservation measures include decreased golf course irrigation and comprehensive water re-use systems and storage. Beginning in 2021, demand was decreased by 10 percent to reflect water re-use and decreased irrigation, with an additional 4 percent reduction in 2022. Thus, the 26 percent reduction by implementing EO 13514, plus the 10 percent reduction in 2021 and the additional 4 percent reduction in 2022, equals a 40 percent reduction in demand. This scenario also incorporates moderate climate change.

Scenario 4 Results

Incorporating climate change and conservation, the garrison demand would be approximately 27,252 m³/day (7.2 MGD) with comparative annual costs of \$10 million. Although the overall efficiency is not applied to the regional level, the lower garrison demand slightly reduces the overall water deficit to 6.9 million m³/day (1821 MGD) as compared to Scenario 1.

Scenario 5: Worst Case-Increased Demand but Lower Precipitation

A worst-case scenario reflects a possible reduction in overall precipitation of 5 percent with demand increasing due to population growth and rising temperatures. An overall reduction in precipitation creating severe droughts is highly likely. As such, this worst case scenario reflects the possible increase in demand coupled with a reduced supply that would likely increase the overall unit price for water.

Scenario 5 Results

These circumstances create a more severe deficit of 11.1 million m³/day (2937 MGD) with a garrison demand matching Scenario 1 of 31,794 m³/day (8.4 MGD). Although a standard unit price of \$3.80 per 1000 gal (3870 L) was used to keep comparisons relative, it is likely water prices would increase due to water shortages.

Scenario 6: 80 percent End State

Since the actual end state of USAG-H is not expected for another 10 years, the exact nature or extent of growth is variable. This last scenario estimates demand for the garrison assuming that it reaches only 80 percent end state capacity. This scenario also takes into account moderate climate change factors.

Scenario 6 Results

Since there are approximately 25.5 million residents in addition to USAG-H using the Han River Basin, the relative size reduction of USAG-H in this scenario has little impact on the regional water demand. With the 80 percent garrison demand adjusted for moderate climate change, a demand of 27,630 m³/day (7.3 MGD) is expected for the garrison and a 6.9 million m³/day (1821 MGD) deficit for the region. Comparative costs for this 80 percent end state are estimated at \$10.1 million.

Conclusions

Although climate change is expected to increase the precipitation in the Han River Basin in South Korea, the overall demand will likely exceed supply to a greater extent in 2040 as compared to 2009. However, it is worth noting the relative deficits of water supply vs. demand of both the moderate and extreme climate scenarios are almost identical, with 1822 MGD, 1821 MGD, and 1821 MGD (~6.9 million m³/day) in Scenarios 1, 3, and 4, respectively (Table 9). South Korea is likely to increase storage through dam construction to offset the forecast deficits. However, it is unknown as to when, and to what extent, South Korea will be able to increase

supply beyond demand. Due to USAG-H relatively minor impact on regional demand, it appears the installation is unlikely to see water shortages affecting their direct supply. However, on a regional basis, the annual supply shortages of the Han River Basin and dam construction costs may result in higher contracted unit water prices for the installation.

Water efficiency factors in Scenario 4 have little impact on the deficit in the water balance compared to Scenario 1, except for the reduction in demand by USAG-H and its associated cost. Thus, the end state cost estimate may serve as a deciding factor regarding the extent of the water conservation measures to be implemented. Scenario 4 demonstrates that a total water program that achieves 40 percent reductions in water demand could save \$1.7 million annually compared to Scenario 1's implementation of the minimum required reductions.

Probably the most important factor to the regional water supply is the annual precipitation expectation. The worst case (Scenario 5) reflects a situation, although unlikely according to the IPCC, that shows the most extreme imbalance of 11.1 million m³/day (2944 MGD) of demand exceeding supply due to limited precipitation. Despite the likelihood of continuously lowered precipitation, increased year-to-year extremes in South Korean precipitation may result in more frequent and severe droughts. Thus, a deficit similar to Scenario 5 is likely to occur at least once between now and 2040. To that extent, the installation should expect, and plan for, water shortages and/or prices hikes to offset demand.

Recommendations

South Korean plans to mitigate its water imbalance will likely focus on more storage via dams, water recycling/reuse, or desalination. Whatever its solution, USAG-H will likely see the new infrastructure costs in their unit prices. Due to the continuous potential for further conflict in the region, water supplies relying strictly on municipal systems should be of concern in the case of contingencies. For such events, water storage on garrison should reflect the potential for limited municipal supply. Pump capacity on base is limited to 4428 m³/day (1.17 MGD) with the possibility of lower capacity caused by salt water intrusion. Therefore, a new emergency water operating plan should be written to direct operations to reflect these factors. If contingency scenarios demonstrate a need for additional wells beyond 1.17 MGD, then considerations should be made for land acquisition or leasing of wells east of the fault line outside the garrison's borders.

As USAG-H works closely with its South Korean counterparts, it should also continue this relationship regarding use of their natural resources. With its long history in working partnership and stewards of their facilities, such cooperation can, and should, expand to water conservation practices and design. By promoting the garrison's conservation practices and environmental protection, local nationals will likely improve their opinion of US forces on the peninsula. Most, if not all, wastewater created at the garrison will be pumped and treated off-base. However, USAG-H should consider retaining its current wastewater plant to treat and re-use some of its wastewater for irrigation or aboveground purposes to lower its overall demand. Current K water policy gives a 30 percent discount towards services for customers who treat and recycle their wastewater (K Water 2009). Potential discounts from maintaining the current wastewater treatment plant on the installation, resulting in lower overall demand, should be explored in a cost benefit analysis. Furthermore, the recycled water may serve as an additional contingency option and source, if the garrison were forced to rely strictly on its wells.

Climate change considerations should also extend to responses to extreme weather. IPCC forecasts higher frequencies in extreme weather, not only drought, but extreme precipitation. Although ground elevation has been raised for the installation expansion, the rise in sea level and frequency of typhoons should be part of the emergency water plan scenarios.

It is recommended that USAG-H take the following measures:

- Immediate:
 - Incorporate water efficient designs and fixtures into as many aspects of garrison expansion as possible.
 - Update the Emergency Water Plan to reflect the needs of the end state garrison based on current well capacity. Delineate essential operating procedures and practices to maintain garrison population until family members and all non-essential personnel are evacuated or re-supplied.
- Short Term:
 - Expand current water storage capacity to the extent required by the updated Emergency Water Plan.
 - Upgrade the waste water treatment plant and incorporate its recycled product for non-potable use.
- Long Term:
 - Continue annual water quality testing of existing wells and consider further land acquisition or leasing east of the fault line where further groundwater sources may be tapped.

5 Conclusions and Recommendations

Regional Summaries

USAG Grafenwöhr

USAG Grafenwoehr, Germany is transforming from a population of 38,930 in 2010 to an expected population of 42,500 by 2013 due to Efficient Basing-Grafenwoehr (EBG). Like much of Germany, USAG-G has a commendable record on water services. Limited regional growth and mild climate change projections coupled with low water consumption and high levels of supply combine to ensure sustainable water supplies. Nonetheless, there are opportunities for improvement. USAG-G is the largest regional consumer and maintains the largest per capita consumption rate. With improved tracking of how and where water is being used on base and appropriate efficiency measures in place, USAG-G may secure cooperative relationships with its neighbors.

USAG Vicenza

US Army Garrison Vicenza is projected to absorb four battalions currently stationed in Bamberg and Schweinfurt, Germany by FY2011. AFRICOM personnel are also likely to be stationed at USAG-V. In all, the total number of stationed troops in Vicenza is projected to rise to at least 4200. Issues of general concern for the region indicate a progressive reduction in groundwater reserves as the area is one of the wealthiest, most industrialized, and most heavily visited regions in Italy. Expected impacts of climate change include warmer temperatures and decreased precipitation, although the intensity of the rain events will increase. Although current water quantity is of significantly less concern than is water quality, the region should anticipate the potential for future water stress.

USAG Humphries

USAG-H will undergo one of the largest garrison transformations in the Army. As the chosen new site for the 8th Army Headquarters, it will become the headquarters for all Army tactical operations in theater. The garrison population of 5200 in 2008 is expected to grow to over 50,000 people by 2020 with the implementation of tour norm stationing. Issues of general concern include the Han River Basin, which serves the most populous province in South Korea, including the largest city, Seoul, and the US

Army Garrison Humphreys. The Han River Basin is shared among North and South Korea. Although water rights have been determined, the countries have not yet reached agreement on joint development of the basin. In fact, North Korea has built large dams and reservoirs along the Han River, ignoring the environmental impacts further downstream. Although South Korea plans to construct additional dams to increase its water storage and availability of water, these plans have been downsized in the past. South Korea receives approximately 70 percent of its precipitation during intense summer rains that often produce flooding while drought-like conditions prevail during the winter. Expected impacts of climate change include an overall increase in precipitation and a gradual increase in temperature through 2040.

Recommendations

All Army installations should be aware of their local water balance, where the water supply is derived, who are the other users of the system, what the projected balance is. Regions at most risk to situations of water scarcity include urban areas in Germany (list of Army installations) and the southern part of Italy (US Army Garrison Livorno). Specifically recommendations follow.

USAG-G

- *Short-Term*
 - Meet EO 13514 efficiency requirements.
 - Update Emergency Water Plan to reflect the needs of the end-state of recent Army transformations.
- *Mid-Term*
 - Conduct visioning exercises concerning water resources and incorporate scenario analyses in master plans.
 - Implement monitoring measures such as meters at individual facilities.
- *Long-Term*
 - Continue to pursue water conservation and efficiency measures.

USAG-V

- *Immediate:*
 - Investment in conservation practices that extend beyond the boundary of the garrison should be explored. As USAG-V is intimately integrated with its surrounding community, so should its conservation of natural resources. Much of the intent of this study is to galvanize the garrison staff to think regionally and coordinate with local officials. Although easier said than done, energy and water conservation requirements may well serve as a segue.
 - Require LEED 3.0 building standards in new building designs (platinum, gold, silver).
- *Short Term:*
 - Implement a high efficiency program that retrofits standard toilet and shower head designs with high efficiency fixtures.
 - As part of new building construction, design surrounding landscape that limits storm water runoff into the municipal system to help mitigate extreme rain events for downstream municipalities.
- *Long Term:*
 - As Veneto Region is forecast to receive more variability in weather, consider green roof designs as a means to lower energy requirements and storm water runoff.

USAG-H

- *Immediate:*
 - Incorporate water efficient designs and fixtures into as many aspects of garrison expansion as possible.
 - Update the Emergency Water Plan to reflect the needs of the end state garrison based on current well capacity. Delineate essential operating procedures and practices to maintain garrison population until family members and all non-essential personnel are evacuated or re-supplied.
- *Short Term:*
 - Expand current water storage capacity to the extent required by the updated Emergency Water Plan.
 - Upgrade the waste water treatment plant and incorporate its recycled product for non-potable use.
- *Long Term:*
 - Continue annual water quality testing of existing wells and consider further land acquisition or leasing east of the fault line where further groundwater sources may be tapped.

References

- 2030 Water Resources Group. 2009. Charting our water future: Economic frameworks to inform decision-making. The Barilla Group, The Coca-Cola Company, The International Finance Corporation, McKinsey & Company, Nestle S.A., New Holland Agriculture, SABMiller plc, Standard Chartered Bank, and Syngenta AG.
- Acque Vicentine S.p.A. 2010. Integrated water service rates. Accessed 25 June 2010, <http://www.comune.vicenza.it/argomenti/scheda.php/42706.45668>
- Ahn, K. H. 2000. New policies and measures for saving a great manmade reservoir providing drinking water for 20 million people in the Republic of Korea. Chungryang, Seoul: Environment and Process Technology Division, Korea Institute of Science and Technology.
- Ali, Saleem H. 2009. Facing Asia's water woes, <http://www.chinadialogue.net/article/show/single/en/3199-Facing-Asia-s-water-woes>
- American Water Works Association (AWWA), and Raftelis Financial Consultants, Inc. 2009. 2998 Water and wastewater rate survey. Denver: AWWA.
- Amschler, Helmut. March 2010. Personal communication. Stadt Grafenwoehr.
- Aquastat. 2010. Information system on water and agriculture. Food and Agricultural Organization of the United Nations, accessed 30 August 2010, <http://www.fao.org/nr/water/aquastat/>
- Asian Water Development Outlook 2007 (AWDO). 2007. Asian Development Bank.
- Asia-Pacific Water Forum (APWF). Accessed 27 August 2009, <http://www.apwf.org/>
- Associated Press. 2009. Flooding across Europe turns deadly. Accessed 27 August 2009, <http://www.msnbc.msn.com/id/31541372>
- Bae, Deg-Hyo, Il-Won Jung, and Heejun Chang. 2008. Long-term trend of precipitation and runoff in Korean river basins. Hydrological Processes. 22:2644-2645. Wiley InterScience, www.interscience.wiley.com
- Barenburg, Michael. 2010. Personal Communication, NR DPW.
- Barrenburg, Michael. 12 May 2010. Personal Communication during USAG Humphreys Visit. NR DPW.
- Bartsch, Susanne. March 2010. Personal communication. USAG-G Public Affairs.
- Bavarian State Office for Statistics and Data. Accessed 9 July 2009, www.regierung.oberpfalz.bayern.de/wfs/dw_opf/bev_new.php
- Biedermann, Norbert. March 2010. Personal communication. O&M Division, USAG-G DPW.
- Biersack, Gerhard. March 2010. Personal communication. USAG-G Housing Office.

- Boschek, Ralf. 2006. The EU water framework directive: Meeting the global call for regulatory guidance? *Intereconomics*. Sept/Oct 2006:268-271.
- Bosetti, Timothy (Chief, Department of Environmental Sciences). 2008. Potable water system master plan. Project Number 31-5T-17834-08. Department of the Army. CMR 402.
- Brekke, Levi D., J. E. Kiang, J. R. Olsen, R. S. Pulwarty, D. A. Raff, D. P. Turnipseed, R. S. Webb, and K. D. White. 2009. Climate change and water resources management: A Federal perspective. Circular 1331. Reston: US Department of the Interior, US Geological Survey, <http://www.usgs.gov/pubprod>
- British Broadcasting Company (BBC). 2009. Italy adopts law to curb migrants. BBC News. Accessed 5 July 2009, <http://news.bbc.co.uk/2/hi/europe/8132084.stm>
- Cecil L. D., D. L. Naftz, P. F. Schuster, D. D. Susong, and J. R. Green. 2010. Satellite image atlas of glaciers of the world: The paleoenvironmental record preserved in middle latitude, high-mountain glaciers—An overview of the US Geological Survey experience in Central Asia and the United States. US Geological Survey Professional Paper 1386-F-8.
- Cho, Ji-hyun. 2009. Water shortage grips Korean Peninsula. *Korean Herald*. Accessed 16 June 2009, http://www.koreaherald.co.kr/NEWKHSITE/data/html_dir/2009/03/23/200903230043.asp
- Cho, Youngsung. et al. 10 May 2004. The Cost benefit analysis of the improvement of water quality in the Paldang Reservoir in Korea. 2004 American Agricultural Economics Association Meeting in Denver Colorado. 1-4 Aug 2004.
- Ciccotti, Anna. 2009. Dal Molin Update: UXO removal, trenching, pile driving moving forward. *The Outlook*. US Army Garrisons Vicenza & Livorno. 42(30). www.USAG.Vicenza.Army.Mil
- Darrow, Jeffery. March 2010. Personal communication. O&M Division, USAG-G DPW.
- Davis, Thomas, and Jung-il Associates. 2006. Yongsan relocation program master plan utility system assessment. Final Submittal. USAEDFE, Unit 15546, APO AP 96205-5546.
- Delaney, John. 2010. Personal Communication, Installation Management Command (IMCOM).
- Division of Early Warning and Assessment, Office for Europe (DEWA~Europe). 2004. Freshwater in Europe – Facts, figures and maps. Chatelaine: UNEP.
- Dong, Oh Byeong. 2009. K Water: Water resource investigation and planning department. Water uses. Webpage. Accessed 13 July 2009, <http://english.kwater.or.kr/>
- EEA. 2009a. Water resources across Europe—Confronting water scarcity and drought. Luxembourg: Office for Official Publications of the European Communities.

- EEA. 2009b. Salt water intrusion map, <http://74.125.93.132/search?q=cache:2wOCERcJhMEJ:dataservice.eea.europa.eu/3F88A083-0452-4A4D-8007-49B2D7A89CDE+salt+water+intrusion+in+European+coasts&cd=1&hl=en&ct=clnk&gl=us>
- EEA. 2009c. The disappearance of the world's wetlands, <http://trendsupdates.com/the-disappearance-of-the-world%E2%80%99s-wetlands/>
- EEA. 2009d. Water resources across Europe—Confronting water scarcity and drought. Report No 2/2009, p 60. Copenhagen, <http://www.eea.europa.eu/publications/water-resources-across-europe/>
- Estrela, Teodoro, Manuel Menéndez, Mirta Dimas, Concepción Marcuello, Gwyn Rees, Gwyneth Cole, Karin Weber, Johannes Grath, Jennifer Leonard, Niels Bering Ovesen, and János Fehér. 2001. Sustainable water use in Europe; Part 3: Extreme hydrological events: flood and droughts. Environmental Issue Report No. 21. Copenhagen: European Environmental Agency. <http://www.eea.eu.int>
- European Environment Agency (EEA). 2005. The European environment- State and outlook 2005. Part C. Country analysis. Copenhagen, <http://www.minenv.gr/4/41/00/The.European.Environment.State.and.Outlook.2005-full.report/Introduction.pdf>
- European Environmental Agency (EEA). 2007. Climate change and water adaption issues. EEA Report No. 2. Copenhagen, European Environmental Agency, http://www.eea.europa.eu/publications/technical_report_2007_2/at_download/file
- European Parliament and of the Council of 23 Oct 2000. Directive 2000/60/EC, Establishing a framework for Community action in the field of water policy. OJ L 327, 22.12.2000, p 77.
- Executive Order 13514. 2009. Federal Leadership in Environmental, Energy, and Economic Performance.
- Farrace, Maria Giuseppina, and G. Pineschi. 2007. Mediterranean strategy for sustainable development monitoring progress and promotion of water demand management policies, Italian national report. Agency for Environmental Protection and Technical Services (APAT) and Ministry of Environment, Sea and Land Protection (MATTM).
- Federal Ministry of Food, Agriculture and Consumer Protection. Website. Accessed 31Aug2020, <http://www.bmelv.de/>
- Federal Republic of Germany. 2002 (1957). Federal Water Act. Wasserhaushaltsgesetz (WHG).
- Gerbens-Leenes, Winnie, A. Y. Hoekstra, and T. H. van der Meer. 2009. The water footprint of bioenergy. Proceedings of the National Academy of Sciences. 106(25):10219-10223.
- German Federal Statistic Office. 2006. Germany's population by 2050-Results of the 11th coordinated population projection. Wiesbaden, <http://www.statistik.bayern.de/english/>

- Gleick, Peter H. 2009. The world's water, 2008-2009- The biennial report on fresh water resources. Pacific Institute for Studies in Development. Washington DC: Island Press.
- Gleick, Peter H., Dana Haasz, Christine Henges-Jeck, Veena Srinivasan, Gary Wolff, Katherine Kao Cushing, and Amardip Mann. 2003. Waste Not, Want Not: The Potential for Urban Water Conservation in California. Oakland: Pacific Institute.
- Gleick, Peter. 2008. Water conflict chronology. Oakland, CA: Pacific Institute for Studies in Development, Environment, and Security, <http://worldwater.org/conflict.html>. accessed 31Aug2010
- Goria, Alessandra, and N. Lugaresi. 2002. The evolution of the national water regime in Italy. EUWARENESS. Istituto per la Ricerca Sociale (IRS). 2000-2002, p 24, www.irs-online.it
- Gruppo 183. 2006. Analysis of the Italian report on river basin districts foreseen by art. 5 of the Water Framework Directive 2000/60/EC. Report Updated 12 Oct. 2006, p 4, http://www.gruppo183.org/dettaglio_documento_en.asp?ID_DOCUMENTO=74
- Han, M., H. Jianjun, and L. Wu. 1995. Potential impacts of SLR on China's coastal environment and cities: A national assessment. Journal of Coastal Research, Special Issue 14: 79-95.
- Harrelson, Danny W. Z. Mansour, and M. Waterbury. 2007. Camp Humphreys groundwater assessment. US Army Corps of Engineers. Engineer Research and Development Center.
- Harrelson, Danny W., Zakikhani, Mansour, Waterbury, and Mathew J. Camp. Sept 2007. Humphreys, Korea, Groundwater assessment. ADA471650. Vicksburg, MS: Engineer Research and Development Center (ERDC), Geotechnical and Structures Laboratory (GSL).
- Harris, Kent. 2008. Caserma Ederle soldiers warned on water. Stars and Stripes. 5 August 2008, <http://www.stripes.com/article.asp?section=104&article=56557>
- Hsu, Robert. 2009. Water security in Asia. Columbia University, <http://blogs.ei.columbia.edu/water/2009/05/05/water-security-in-asia/>
- Hummel, Diana, and A. Lux. 2007. Population decline and infrastructure: The case of the German water supply system. Vienna Yearbook of Population Research 2007, pp. 167-191.
- Hwang, Soon-Jin., Soon-Kuk Kwun, and Chun-Gyeong Yoon. 2002. Water quality and limnology of Korean reservoirs. Paddy and Water Environment 1(1):43-52.
- IDRICA IN VENETO. Dipartimento Regionale per la Sicurezza del Territorio. 31 May 2010, <http://www.regione.veneto.it/channels>
- IMKO-PWD-O. 22 January 2010. Memo: FY 2010 Quarterly Water Costs and Usage. US Army Garrison Humphreys.

- Inman, Mason. 2010. Pakistan flooding because of farms? National Geographic Daily News, <http://news.nationalgeographic.com/news/2010/07/100716-pakistan-flood-farms-river-management-irrigation/>
- Institute of Electrical and Electronic Engineers (IEEE). 2010. The coming clash between water and energy. IEEE Spectrum, <http://spectrum.ieee.org/energy/environment/the-coming-clash-between-water-and-energy>
- Intergovernmental Panel on Climate Change (IPCC). 2010. Fourth Assessment Report: Climate Change 2007: Working Group II: Impacts, Adaption and Vulnerability. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C. E. Hanson (eds.). Cambridge, United Kingdom (UK) and New York, NY: Cambridge University Press, http://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch10s10-3.html#10-3-1
- International Alliance of Research Universities. 2009. Climate change: Global risks, challenges & decisions. Synthesis Report of the UN Conference on Climate Change, 10-12 March 2009. Copenhagen. <http://www.climatecongress.ku.dk>
- Jenicek, Elisabeth, Natalie R. D. Myers, Donald F. Fournier, Kevin Miller, Melena Hessel, Rebecca Carroll, and Ryan Holmes. September 2009. Army installations water sustainability assessment: An evaluation of vulnerability to water supply. ERDC/CERL TR-09-38. Champaign, IL: Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL).
- Jenicek, Elisabeth. 20 May 2010. Trip report to USAG Vicenza.
- Jeon-Heon, Lee. 2009. South Korea fears North's water attack, http://upiasia.com/Security/2009/09/07/south_korea_fears_norths_water_attack/2700
- Jones, Willie D. 2008. How much water does it take to make electricity? IEEE Spectrum. Institute of Electrical and Electronic Engineers, <http://spectrum.ieee.org/energy/environment/how-much-water-does-it-take-to-make-electricity>
- Joon-ho, Choi, S. Myo-ja. 2009. Experts. Nation has plenty of water but inadequate storage. Joongang Daily. Accessed: 23 June 2009, <http://joongangdaily.iains.com/article/view.asp?aid=2902894>
- K Water: Korean Water Source Corporation. Sustainability report 2007. Accessed 30 June 2009, <http://english.kwater.or.kr/>
- K Water: Korean Water Source Corporation. Sustainability report 2009. Accessed 15 June 2010, http://english.kwater.or.kr/EngUser/html/corpo/2009_SMReport.pdf
- Kim, KoUn, J. Koh, and M. Lee. 2005. The dynamics of water policy change in South Korea. Geography and Environment, <http://www.newater.uos.de/.../KoUn%20Kim%20et%20al%202007.pdf>
- Kim, KoUn, J. Koh, and M. Lee. 2007. The dynamics of water policy change in South Korea. Basel, Switzerland: CAIWA 2007: International Conference on Adaptive & Integrated Water Management, 12-15 November 2007.
- Korea National Statistical Office. 2008. Population projections. Accessed 20 June 2009. <http://www.nso.go.kr/>

- Kreamer, R. Andreas, B. Pielen, and C. De Roo. 2007. Regulation of water supply in Germany. DICE Report. 5(2. 2/2007):21-26.
- Kunz, Stefan. March 2010. Personal communication. O&M Division, USAG-G DPW.
- Land Use Policies and Sustainable Development in Developing Countries (LUPIS). July 2008. Regional policy brief for Asia, <http://www.lupis.eu/>
- Länderarbeitsgemeinschaft Wasser (LAWA, Joint Commission of Federal States). 2003. working paper-German Guidance Document for the implementation of the EC Water Framework Directive, Part 2.
- Leadership Group on Water Security in Asia. Asia's next challenge: Securing the region's water future. April 2009, <https://www.policvarchive.org/bitstream/handle/10207/17587/WaterSecurityReport.pdf?sequence=1>
- Liquid Assets. 2008. Penn State public broadcasting, <http://liquidassets.psu.edu>
- Marsili, Marco. 2006. Servizio popolazione instuzione e cultura. Provisioni demografiche nazionali. ISTAT, http://www.istat.it/salastampa/comunicati/non_calendario/20060322_00/nota%20previsioni.pdf
- Massarutto, Antonia. Undated. Agriculture, water resources and water policies in Italy. Undated. SAGA – Sustainable Agricultural Use of Aquifers in Southern Europe: Integration Between Agriculture and Water Management Policies.
- McKeown, Alice, and G. Gardner. 2009. Climate change reference guide. Update to state of the world 2009: Into a warming world. Worldwatch Institute.
- Meneguzzo, Francesco. et al. 2004. Climate Analysis and Prediction Over the Arno River Basin, Italy. Firenze, Italy: Institute of Biometeorology- National Research Council (IBIMET-CNR).
- Ministry of Environment, Republic of Korea. 2004. Water, policies and innovative practices, Republic of Korea 2004, <http://www.me.go.kr>
- Ministry of Land, Transport, and Maritime Affairs (MLTM), Republic of Korea. 2008. Prospect for demand and supply of water. Accessed: 04 June 2010, http://www.mltm.go.kr/DataCenter/StatisticData/08sta/06/06_intro.jsp
- MLTM. 2009. Prospect for Water Demand and Supply. Access 19 June 2009, http://www.mltm.go.kr/DataCenter/StatisticData/08sta/06/06_intro.jsp
- New York Times. 2009. Water infrastructure plays catch-up in Asia, <http://greeninc.blogs.nytimes.com/2009/07/17/water-infrastructure-plays-catch-up-in-asia/?scp=4&sq=europe%20water%20&st=cse>
- Nickum, James E. 2010. Hydraulic pressures (review essay). Foreign Affairs.
- OneWorld.net. 21 April 2009. Conflict simmering in Asia over water, OneWorld South Asia, <http://southasia.oneworld.net/todaysheadlines/conflict-simmering-in-asia-over-water>.

- Organization for Economic Cooperation and Development (OECD). 2000. The price of water: trends in OECD countries. OECD Publishing,
<http://www.oecdbookshop.org/oecd/displav.asp?lang=EN&sf1=identifiers&st1=971999061e1>
- Otto, Stefan. Otto, S. L. Altissimo, and G. Zanin, G. 2007. Terbutylazine Contamination of the Aquifer North of Vicenza (north-east Italy). *Environment Science and Pollution Research*. 14 (2):109–113.
- Park, Peter. April 2009. Directorate of Plans, Training, Mobilization, and Security, USAG-H. Water System Emergency Response Plan. Camp Zama, Japan: US Army Center for Health Promotion and Preventive Medicine.
- PREDICATE. 2004. European climate in the next decade. (PREDICATE is funded by the Fifth Framework Programme (FP5) of the European Union under the Energy, Environment and Sustainable Development thematic programme.),
<http://ugamp.nerc.ac.uk/predicate/public.html>
- Prosl, Dr. Karl-Heinz, and Dr. Johann Rietzler. 2004. *Stadt Grafenwoehr Hydrogeologisches Modell für das Einzugsgebiet "Mittlere Creussen"*. Stadt Grafenwoehr.
- Pyongtaek City. 2009. History and population. Accessed 15 July 2009,
<http://www.pyeongtaek.go.kr/pub/eng/>.
- Pyongtaek City. History and population. Accessed 15 July 2009,
<http://www.pyeongtaek.go.kr/pub/eng/>
- Region del Veneto. Public Relations Office. 2009. Accessed 27 July 2009,
<http://www.regione.veneto.it/Ambiente+e+Territorio/Ambiente/Acqua+e+difesa+del+suolo/Acqua/Approfondimenti.htm>
- Regional Department for homeland security (Dipartimento Regione per la Sicurezza del Territorio). May 2010. Report on Veneto regions water sources (Rapporto sulla risorsa idrica in Veneto)., http://www.arpa.veneto.it/acqua/docs/interne/Rapporto_risorsa_idrica_Veneto_31-05-2010.pdf
- Regione Del Veneto. 2007. Statistical Report 2007. Sect. 1.2. Access 14 July 2009.
<http://statistica.regione.veneto.it/ENG/Pubblicazioni/RapportoStatistico2007/Capitolo01b.isp#top>
- Regione Del Veneto. 2008. Strategic environmental assessment (SEA) plan for protection of water-non-technical summary. Annex B. DGR.n. 1518 of 17 June 2008,
<http://www.regione.veneto.it/NR/rdonlyres/C7F704D0-45BD-44EC-A509-953A56D31C27/0/dgr1518del17giugno2008ALLB.pdf>
- Report on Veneto Regions Water Sources. May 2010. *Rapporto Sulla Risorsa Idrica in Veneto*. Dipartimento Regionale per la Sicurezza del Territorio. 31 May 2010.
<http://www.regione.veneto.it/channels>.
- Republic of Korea Ministry of Land, Transport and Maritime Affairs (MLTM). 2008 Han River Basin case study report.
- Republic of Korea Ministry of Land, Transport and Maritime Affairs. 2008 Han River Basin Case Study Report.

- Reuters. 2001. South Korea drafts troop to fight 100 year drought,
<http://edition.cnn.com/2001/WORLD/asiapcf/east/06/12/skorea.drought.01/>
- Rick, Manfred. March 2010. Personal communication. Environmental Division, USAG-G DPW.
- Roth, Evelyn. March 2010. Personal communication. Master Planning, USAG-G DPW.
- Sartori, Michael. 15 November 2009 to 15 May 2010. Personal Communication (telephone and interview). DPWC-ESS.
- Seto, Karen C., and J. M. Shepherd. 2009. Global urban land-use trends and climate impacts. *Current Opinion in Environmental Sustainability*. 1(1):89-95.
- Smith, Lewis. 24 June 2010. Personal Communication (telephone). DPWC-Housing.
- Smith, T. S., R. A. Ducey, W. J. Stein, and W. D. Goran. 2010. Tradeoffs for renewable energy projects: Environmental, planning, and mission considerations. ERDC/CERL Special Report 10-2. Champaign, IL: Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL).
- Sordid, Fernando Navarro. 2006. Europe warns of water shortages,
<http://www.cafebabel.com/eng/article/18682/europe-warns-of-water-shortages.html>
- Stars and Stripes. 2001. A look at water quality on Army bases in Europe. 21 May 2001. Stars and Stripes. <http://www.stripes.com/01/may01/ed052101k.html>
- Thicken, Ann egret H., H. Kreibich, M. Muller, and B. Merz. 2007. Coping with floods: Preparedness, response and recovery of flood-affected residents in Germany in 2002. *Hydrological Sciences*. 52(5):1016-1037.
- Umwelt Bundes Amt. 2007. Regional climate changes: Recent findings.
- UN World Water Assessment Programme (WWAP). April 2009. The United Nations world water development report 3: Water in a changing world (Two Vols.),
<http://www.unesco.org/water/wwap/wwdr/>
- United Nations Environment Program (UNEP). 2002. The Atlas of international freshwater agreements. Nairobi: UNEP.
- United Nations Environment Program (UNEP)/Division of Early Warning and Assessment (DEWA). 2004. Freshwater in Europe: Facts, figures and maps. Chatelaine: UNEP/DEWA~Europe.
- United Nations Population Division. 2009. Population prospects: The 2008 revision. Population Database. New York: United Nations,
<http://esa.un.org/unpp/>
- URS Greiner Woodward Clyde Inc. 2003. Vicenza Aquifer Assessment. Villagio Housing Area. Vicenza Italy. Heinrich-Hertz-Str. 3. 63303 Dreieich-Germany. October 2003.
- URS Greiner Woodward Clyde Inc. October 2003. Vicenza aquifer assessment. Villagio Housing Area. Vicenza Italy.

- USAG-G DPW, O&M Division, Utilities Branch. 2006. USAG-Grafenwoehr potable water system master plan.
- USAG-G DPW, O&M Division, Utilities Branch. 2006. USAG-Grafenwoehr utility data cards.
- USAG-G DPW, O&M Division, Utilities Branch. 2008. Water supply management program: Water system emergency response plan.
- USAG-G DPW, O&M Division. 2010. USAG-Grafenwoehr real property.
- USAG-G. 2006-2010. USAG-Grafenwoehr population census: Summary.
- USAG-H Master Planning. 18 December 2009. 2009 Master plan update: Final. US Army Garrison Humphreys, Korea, <https://8army.korea.army.mil/sites/imcom/area3/dpw/MPD/default.aspx>
- USAG-H Master Planning. 2009. USAG-H Master planning spreadsheet, tour norm population and costs: 2 July 2009. USAG-H Master Planning Website. Accessed 08 June 2010, <https://8army.korea.army.mil/sites/imcom/area3/dpw/MPD/default.aspx>
- USAG-H Master Planning. 2010. Power point presentation provided by USAG-H DPW Master Planning Office.
- Vickers, Amy. 2001. Water use and conservation. Amherst, MA: Water Plow Press.
- Wachter, Helmuth (Mayor, City of Grafenwoehr). March 2010. Personal communication.
- Walsh, Bryan. 2007. Why is Asia ignoring global warming. Time, <http://www.time.com/time/health/article/0,8599,1617639,00.html>
- Water Vicenza. 2010. Integrated water service rates. Accessed 25 June 2010, <http://www.comune.vicenza.it/argomenti/scheda.php/42706.45668>
- Westbrook, Stephanie. 2009. US military base in Vicenza, Italy gets final approval. Center for Research on Globalization, <http://www.globalresearch.ca/>
- WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation. 2005. Water for life: Making it happen. Geneva: World Health Organization.
- World Economic Forum and Cambridge Energy Research Associates. 2008. Energy vision update 2009, thirsty energy: Water and energy in the 21st century. Geneva: World Economic Forum.
- Xianzhi, Li, ed. 2009. Drought leaves 900 ships stranded in S. China. http://news.xinhuanet.com/english/2009-10/13/content_12219894.htm
- Yanefski, Jessica. 2010. Land use profile of China. The Encyclopedia of Earth. Accessed 2 Sep 2010, http://www.eoearth.org/article/Land_use_profile_of_China

- Zanin, Giuseppe, Maurizio Borin, Lorenzo Altissimo, and Davide Calamari. 1993. Simulation of herbicide contamination of the aquifer north of Vicenza (north-east Italy). *Chemosphere*, 26(5):929-940. Accessed 20 June 2010, http://www.sciencedirect.com/science?_ob=MImg&_imagekey=B6V74-488899G-JG-1&_cdi=5832&_user=930810&_pii=004565359390367E&_orig=search&_coverDate=03%2F31%2F1993&_sk=999739994&_view=c&_wchp=dGLzVzz-zSkWb&md5=37a8f60b681c072a026614749423adf7&ie=/sdarticle.pdf
- ZARAGOZA. 2007. National report of Italy: Water demand management in the Mediterranean, progress and policies. APAT.

Acronyms and Abbreviations

<u>Term</u>	<u>Definition</u>
ABCT	Airborne Brigade Combat Team
ADB	Asian Development Bank
AEPI	Army Environmental Policy Institute
AESIS	Army Energy Security Implementation Strategy
AFRICOM	US African Command
ANSI	American National Standards Institute
APAT	Agenzia per la Protezione dell'Ambiente e per i servizi Tecnici, Italy's Environmental Agency
APWF	Asia-Pacific Water Forum
AR	Army Regulation
ARPAV	Agenzia Regionale per la Prevenzione e protezione Ambientale del Veneto (Environmental Agency of the Veneto Regional Government)
ATO	Optimal Territorial Areas
AWDO	Asian Water Development Outlook
AWWA	American Water Works Association
BBC	British Broadcasting Company
BBRB	Brenta-Bacchiglione River Basin
BOD	biological oxygen demand
BRAC	Base Realignment and Closure
BSOSD	Bavarian State Office for Statistics and Data
CASI	Center for the Advancement of Sustainability Innovations
CERL	Construction Engineering Research Laboratory
CFE	Conventional Forces Europe
DG	Directorate General
DOD	US Department of Defense
DOI	US Department of Interior (DOI)
DPW	Directorate of Public Works
EBG	Efficient Basing-Grafenwoehr
EC	European Commission
ECA	European Climate Assessment & Dataset
EEA	European Environmental Agency
EISA	US Energy Independence and Security Act of 2007
EO	Executive Order
ERDC	Engineer Research and Development Center
EU	European Union
FY	fiscal year
GDP	Gross Domestic Product
GEE	(Far East) Geotechnical and Environmental Engineering Branch

<u>Term</u>	<u>Definition</u>
GFSO	German Federal Statistics Office
GIS	geographic information system
GSL	Geotechnical and Structures Laboratory
IAHS	International Association of Hydrological Sciences
IBIMET-CNR	Institute of Biometeorology – National Research Council
IDWA	Index of Drinking Water Adequacy
IMCOM	Installation Management Command
IPCC	Intergovernmental Panel on Climate Change
IRS	Istituto per la Ricerca Sociale
LAWA	Länderarbeitsgemeinschaft Wasser (Joint Commission of Federal States)
LEED	Leadership in Energy and Environmental Design
LSE	London School of Economics
MG	million gallons
MGD	million gal/day
MGY	million gallons per year
MLTM	Korean Ministry of Maritime and Land Transportation Management
MLWM	(Korean) Ministry of Land, Water and Maritime
MM	ModelManager
MW	megawatt
MWR	morale, welfare, and recreation
NATO	North Atlantic Treaty Organization
NSN	National Supply Number
OECD	Organization for Economic Cooperation and Development
OMB	Office of Management and Budget
PO	Post Office
PWSMP	Potable Water System Master Plan
RBA	River Basin Authority
RBD	River Basin District
SAR	Same as Report
SCR	Stryker Cavalry Regiment
SEA	Strategic Environmental Assessment
SF	standard form
SLR	Sea Level Rise
TDS	total dissolved solids
TR	Technical Report
TWM	total water management
UIUC	University of Illinois at Urbana-Champaign
UK	United Kingdom
UN	United Nations
URL	Universal Resource Locator
USACE	US Army Corps of Engineers
USAG	US Army Garrison

<u>Term</u>	<u>Definition</u>
UXO	unexploded ordnance
WEI	Water Exploitation Index
WFD	Water Framework Directive
WHG	Wasserhaushaltsgesetz (Federal Water Act)
WISE	Water Information System for Europe
WWAP	[UN] World Water Assessment Programme
WWII	World War II
WWW	World Wide Web
YRP	Yongsan Relocation Program

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